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British Journal of Anaesthesia

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"*I would have everie man write what he knowes and no more.*"—MONTAIGNE

BRITISH JOURNAL OF ANAESTHESIA

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EDITORIAL

AN EXPERIMENT IN COMMUNICATION

On February 19, 1958, there was an experiment in communication in Leeds. The idea is not new, it was born in the United States of America in 1930, when Mrs. Kate Macy Ladd set aside a fund to be used, not for the construction of buildings for research, but for the "architecture of ideas." The universities too often worked in watertight compartments, and the interdepartmental barriers grew stouter with the advances of the specialist. When heads of departments met it was to discuss university politics, to decide on high policy and to appoint committees; rarely was research the attraction.

Progress demands that these barriers be broken to let loose ideas, and these may set problems which single departments are unable to solve by themselves. They require teamwork by men of different specialities; but teams are difficult to form because abilities and personalities have to be reconciled.

The experiment in communication is likely to be the origin of teamwork on a grand scale. Members of different disciplines meet—sometimes for the first time—round a table informally. For some days they talk and live together, and often more will be learnt outside than in the conference room.

The symposium in Leeds only lasted for one afternoon; it dealt with the problems of pulmonary ventilation. This is a practical problem all anaesthetists meet daily, physicians face it in treating poliomyelitis patients or those with tetanus; obstetricians are concerned with the first breaths of life, and to measure these, taxes the ingenuity of the physicist and engineer.

The symposium was limited to a small number including anaesthetists, physicians, physiologists, a pharmacologist, physicists and an obstetrician, and the informal talks and discussions were recorded. A report of the meeting will be published shortly under the auspices of this Journal. It is hoped that the experiment will be the forerunner of others, and that more time be given to them.

In Britain the Ciba Foundation has tried an experiment of this kind and the results have been published in the form of monographs of which "Peripheral Circulation" and "Visceral Circulation" are two well-known examples. These monographs differ from the American pattern in that the material from papers predominates in the British experiments, whereas the discussions are the feature of the American series. Ideas are more likely to come from discussions of papers, rather than from the papers themselves. The Americans aim to start with a given aspect of a paper, and the discussion is so extensive that there is no time for long papers. The ideas then stimulate others to work, and when the group meets again, some of the problems may be solved. The success of an international conference of this kind depends on the calibre of the participants and on its organization; it should lead to a type of lasting co-ordination in research because it arises out of interest and not compulsion.

In this way men can learn to communicate and to work together although separated by vast spaces, even by continents.

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THE HEAT MECHANICS OF THE WATERS CANISTER

BY

J. C. AINLEY-WALKER

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WATERS' carbon dioxide (CO_2) filter was designed to enable anaesthetic gas mixtures to be rebreathed, rather than discarded into the theatre air, and so economize gases and vapours (Waters, 1924, 1936). This function it fulfilled admirably and it made possible the extensive use of cyclopropane which was such a boon before the introduction of the relaxant drugs. A further advantage claimed for to-and-fro carbon dioxide absorption was conservation of heat and of water vapour, which was alleged to reduce "surgical shock" and so to benefit particularly the very sick patient; the implication was that patients tended to lose heat and become cold during anaesthesia and surgery. Portability and simplicity were also features of the apparatus.

Some years later Adriani and his colleagues (Adriani and Rovenstine, 1941; Adriani and Byrd, 1941; Adriani, 1946) examined the functioning of the Waters canister with particular regard to its absorbing efficiency under various conditions of carbon dioxide output, tidal volume, minute volume, and respiratory rate, and of grade of soda lime. They showed by laboratory and clinical experiments that the canister worked most efficiently if it were in the form of a cylinder measuring 8 cm × 13 cm (the dimensions specified by Waters) and filled with 4–8 mesh soda lime; this gave an intergranular space of about 450 ml, a resistance to respiration of less than 0.5 cm H_2O, and an inspired carbon dioxide concentration of less than 0.5 per cent for over 5 hours with a 200 ml/min carbon dioxide output. They also measured temperatures in the canister and under the mask and showed that the temperature of the soda lime might reach 55–60°C, whilst that under the mask might be 30–35°C in the circle system and 40–42°C in the to-and-fro system. The temperature peak in the soda lime moved from front to back as the centre of maximal absorptive activity moved progressively backwards. This rise of temperature is due to the chemical reaction taking place between the carbon dioxide and the hydroxides of sodium and calcium. If it does not occur it implies that carbon dioxide is not being absorbed. A rise of temperature can also be caused by the heat of solution of sodium hydroxide in the water formed during the chemical reaction; the soda lime must, therefore, be hard enough not only to make it reasonably dust-free, but also to reduce this tendency to solution which causes it to get excessively hot and to cake. It must, however, at the same time be soft enough for easy penetration by carbon dioxide and water.

Anaesthetists have from time to time expressed anxiety about the effects that the hot canister may have upon the patient. Adriani (1946) mentions that the "heat from the reaction may become an objectionable feature in the to-and-fro unit because of the proximity of the canister to the facepiece", but gives no reasons just why it may be objectionable; other writers have made similar remarks. It seems to be tacitly assumed that when the canister is used the inspiration of hot gases will cause ill effects, either reflexly, or by preventing normal heat loss, or even by actively heating the patient; but there seems to be little agreement, and less evidence, as to what may be the untoward effects. None the less, many anaesthetists routinely change the canister as soon as it becomes at all hot; and others never use the to-and-fro unit at all, preferring to keep the carbon dioxide absorber well away from the patient by a circle system, which however has its own disadvantages. Manufacturers have sometimes received complaints that their brand of soda lime is unsatisfactory because it becomes too hot.

Recognizing, then, that heat must inevitably be liberated it was decided to try to improve heat dissipation from the surface of a canister, and then to compare the performance of a normal and of the modified canister with regard to (*a*) temperatures reached in the interior and at the surface, (*b*) inspired gas temperatures, for known carbon dioxide absorption rates.

MODIFICATION OF THE CANISTER

Heat produced in the canister may be dissipated by conduction, convection, and radiation; and also, as was later realized, by evaporation of water from the interior. Conduction seems likely to play very little part because the usual contacts —pillow, drapes, and air—are poor conductors. Convection also seems unlikely to be important (except in an exceptionally draughty theatre!) unless the stream of anaesthetic gases washing to and fro inside the system gives up significant amounts of heat either to the patient or to the theatre air via the reservoir bag and corrugated tubing. Radiation is the obvious mechanism and can, indeed, be easily felt on the hand. It is apparent, on consideration, that the canister is not well adapted for radiating, both because it has a relatively small surface/volume ratio and because the surface is brightly polished. The surface/volume ratio could be improved by fundamentally altering the shape, but this might reduce the carbon dioxide absorbing efficiency and increase the resistance to gas flow (Waters, 1936; Adriani and Byrd, 1941), and so it was decided to leave the basic configuration of the canister unaltered. The second factor—the brightly polished surface—could easily be removed by blacking.

An ordinary canister was, therefore, blackened with Berlin Black paint; its rate of heat dissipation was determined and compared with that of a standard canister. A series of longitudinal copper fins were then sweated on to the surface to increase the total surface area and, it was hoped, increase the total radiation. The rate of heat dissipation was determined again.

HEAT DISSIPATION OF THE CANISTER

Heat dissipation by a perfectly black body is expressed by the Stefan-Boltzmann Law, which states that the total energy radiated is proportional to the fourth power of the absolute temperature. Thus if a body is at an absolute temperature of T_a^0K, and its surroundings at T_b^0K, then the rate at which the body loses heat is proportional to $T_a^4—T_b^4$. For small differences of temperature Newton's Law of Cooling can be applied, which states that for moderate differences of temperature the rate of cooling of a body is directly proportional to the difference of temperature between the body and its surroundings.

Determination of heat dissipation.

The canister was filled with almost boiling water, corked up, and laid horizontally in a black wooden stand which supported it only at the very ends (fig. 1); this was placed clear of other objects, in a room as free from draughts as possible to limit convection. The temperature of the water and room temperature were recorded frequently during cooling; the surface temperature was practically identical with that of the contained water. Cooling curves were plotted of the temperature difference between the surface and the surrounding air against time. By drawing tangents to the curve at various points and measuring their angles to the horizontal, one can estimate the rates of change of temperature at the various points selected (fig. 1). Knowing the specific heats of the canister (brass) and of water the rates of heat dissipation in calories per second (cal/sec) can be calculated for the various differences of temperature between the surface and the room air. In order to obtain a straight line graph (passing through the origin, of course) the heat dissipation values were plotted against the difference between the fourth power of the surface temperature and the fourth power of the room temperature (fig. 2). The tangents of the angle of slope of the graphs so obtained give a direct comparison of the heat dissipating powers of the canisters. Some convectional loss of heat must occur too, but the conditions were designed to keep this low.

The results are tabulated in table I, and show the relatively greater heat dissipating power of the black and of the blacked and finned (modified) canister. The results with the black and with the modified canister were more closely reproducible than those with the standard one, possibly because variations in the degree of surface polish of the standard canister made more difference than was realized at the time; the heat dissipating power of the modified canister has therefore been taken as 1.0, and that of the standard one expressed as a fraction of this; but to show more clearly the effect of blacking and finning a canister the last column shows the relative heat dissipating powers taking the standard canister as 1.0. From the figures it appears that blacking a canister improves its heat dissipating power by about 60

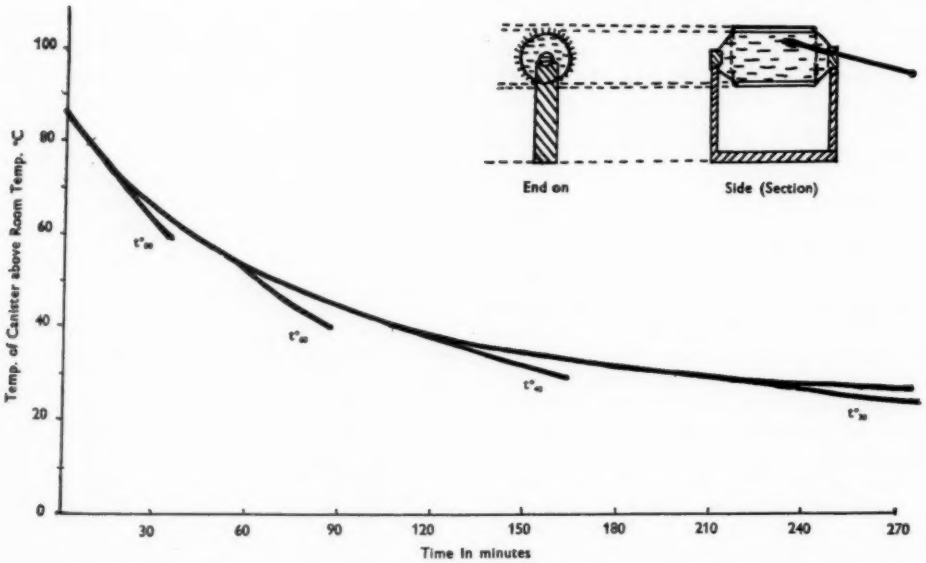

FIG. 1

Diagram of a typical cooling curve of a waters canister. The angles t°_{80}, t°_{60}, t°_{40}, t°_{20}, are those between the tangents to the curve at points 80°C. 60°C, 40°C, 30°C, above room temperature respectively and the horizontal. Inset is a diagram showing how the canister was set up to obtain the cooling curve: the water temperature was practically identical with, and was taken as the same as, the surface temperature.

TABLE I

Comparison of heat dissipating power of a standard canister and of the modified canister

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Standard canister		Black canister				
Room temp.	Slope, α°	Tan. α°	Slope, β°	Tan. β°	Tan α° / Tan. β°	Mean Tan α° / Tan. β°	Mean Tan. β° / Tan. α°
17°C	40.5	0.854	52.3	1.294	0.658		
25°C	38.0	0.781	49.0	1.150	0.678	0.625	1.60
20°C	33.5	0.662	49.5	1.170	0.566	±0.043	±0.11
18°C	35.0	0.700	49.5	1.170	0.597		
		Mean Tan. α°	Modified canister		Tan. α° / Tan. γ°	Mean Tan. α° / Tan. γ°	Mean Tan. γ° / Tan. α°
			Slope, γ°	Tan. γ°			
18.3°C		0.749	53.6	1.357	0.552	0.552	1.82
19°C		±0.066	53.6	1.357	0.552	±0.05	±0.16

α°, β°, and γ° are the slopes of the graphs in figure 1 for the standard, the black and the modified canisters respectively.

Column 7 gives the ratio $\frac{\text{Heat dissipating power, standard canister}}{\text{Heat dissipating power, black canister.}}$

Column 8 gives the reciprocal of this.

The lower part of column 7 gives the ratio $\frac{\text{Heat dissipating power, standard canister}}{\text{Heat dissipating power, modified canister}}$

The lower part of column 8 gives the reciprocal of this.

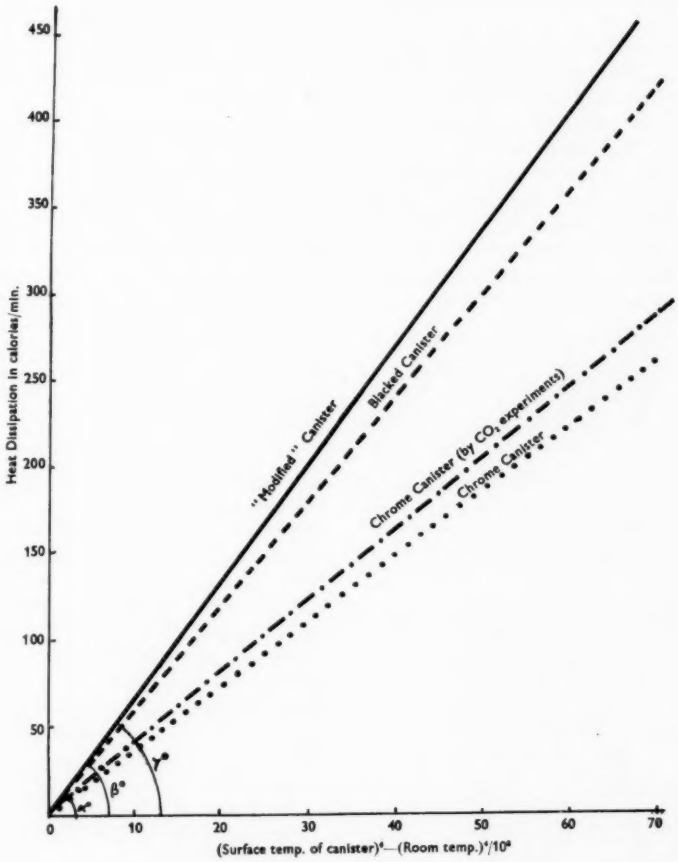

FIG. 2

Graphs showing the relative and absolute heat dissipating powers of the standard, the blacked, and the modified (blacked and finned) canisters. Below is a specimen calculation to show how the graphs are obtained from a cooling curve such as that shown in figure 1.

Specimen Calculation from a Cooling Curve.

Weight of canister: 385 g
Sp. heat of canister (brass): 0.093
∴ Water equivalent of canister=35.8 g
Weight of water in canister=702 g
∴ Total water equivalent=737.8 g
Rate of change of temperature at a temperature 30°C above room temperature =tan 10° degrees C/min=0.176°C/min.
∴ Rate of heat dissipation=737.8×0.176
=130 cal/min.

per cent, and adding fins increases this by about another 20 per cent.

Next, to check the validity of these figures, measurements were made of the interior and surface temperatures at equilibrium when carbon dioxide was run through the canisters. Equilibrium was established when the rate of heat dissipation equalled the rate of heat production, and was taken to have been reached when the mean of three interior temperatures had not altered by more than 1°C in the previous 15 minutes, or the surface temperature by more than 0.5°C in the same period.

Determination of heat dissipation by the carbon dioxide method (fig. 3.)

The canister was charged with fresh soda lime, and attached to the ordinary tube feed mount. The expiratory valve and open end of the mount were made gastight with plastic adhesive tape. The canister and mount were then set up on end, with the mount downwards, so that the carbon dioxide was admitted at the bottom and gradually pushed upwards through the canister; an empty bag was attached at the top end of the canister to show that all the carbon dioxide was being absorbed. Surface temperatures were recorded by thermometers strapped to the canister; good thermal contact was ensured by surrounding the bulb with a wall of modelling clay and filling the small space left with mercury. The flow rate of carbon dioxide was 200 ml/min and the flowmeter was calibrated and suitable correction made in the calculations.

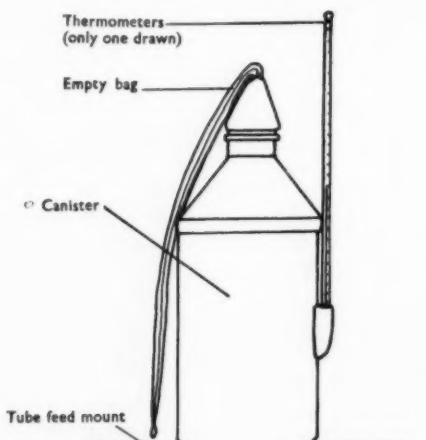

FIG. 3
Determination of heat dissipation by CO_2 method; the apparatus used.

The results are listed in table II. The ratio in column 6 shows the relative heat dissipating power of the modified and standard canister during carbon dioxide absorption. The errors involved in these experiments are greater than in the cooling ones because surface temperatures are not quite uniform over the canister, and the interior temperatures recorded depend both on the position in the canister and on the closeness of contact of the thermometer bulb with the soda lime granules; however, it was possible to obtain mean values steady within 1°C for interior and 0.5°C for surface temperatures.

The results agree passably well with those obtained from the cooling experiments, but suggest that the modified canister was not performing quite so well as before. However, assuming the performance of the modified canister to be the same as in the earlier cooling experiments, and using the value 0.61 for the relative heat dissipating powers, a graph can be drawn from which absolute heat dissipation can be read off in cal/min (fig. 2). Adriani (1946) gives a figure of about 13,500 cal/mole of carbon dioxide; but the figure given by these experiments is far higher, thus:

Heat dissipation deduced from CO_2 experiments = 1.02 cal/ml CO_2.

Ditto, calculated from Adriani's figure = 0.56 cal/ml CO_2.

This difference is far more than can be accounted for by experimental error. Moreover the heat dissipation deduced from the graph, which is itself obtained from the cooling experiments, is likely to be an under-estimation since, with the canister on end, convectional losses are likely to be rather bigger, and the room used was not as draughtproof as the one in which the cooling experiments were done. The discrepancy, therefore, indicated either that there was some gross error involved in deriving absolute heat dissipations from the cooling curves, or that Adriani's figure was wrong. A thermochemical reference work (Bichowsky and Rossini, 1936) indicated a number of figures for heat liberation which varied

TABLE II

Comparison of heat dissipating power of a standard canister and of the modified canister using a known rate of flow of CO_2.

(1)	(2)	(3) Standard canister	(4)	(5) Modified canister	(6) Ratio Column 5 / Column 3
Room temp.	Mean surface temp.	(Surface temp. °K)⁴ −(Room temp. °K)⁴	Mean surface temp.	(Surface temp. °K)⁴ −(Room temp. °K)⁴	
18.3°C	60.6°C	$(124-72) \times 10^8$			0.609
21.8°C			49.0°C	$(107.5-75.8) \times 10^8$	0.631
21.8°C	61.7°C	$(126-75.8) \times 10^8$			0.607
20.3°C			46.7°C	$(104.5-74) \times 10^8$	
	Means	51.1×10^8		31.1×10^8	0.608 ± 0.011

0.609, 0.631, 0.607 → 0.587

The figures in columns 3 and 5 are a measure of the heat dissipating power of the standard and the modified canisters; the higher the surface temperature reached the less the heat dissipating power. The ratio in column 6 is therefore the ratio $\frac{\text{Heat dissipating power, standard canister}}{\text{Heat dissipating power, modified canister.}}$

according to the degree of hydration of the end products of the reaction; sodium hydroxide can form a mono- and a deca-hydrate, and $Ca(OH)_2$ can also form hydrates. Assuming the simplest reaction, thus:

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$$

with the NaOH acting as a catalytic intermediary, the amount liberated is 27,500 cal/mole carbon dioxide at 25°C which is 1.15 cal/ml carbon dioxide at 20°C and 760 mm Hg. This fits quite well with the figures deduced from the surface temperatures of the carbon dioxide experiments and the heat dissipation graphs.

Determination of total heat production.

In order to verify the total heat production a calorimeter was constructed from sheet zinc into which a canister could be sealed water-tightly. The experiments described above were then repeated (except that no direct measurements of canister temperatures were made), with a known volume of water almost completely filling the space between the contained canister and the calorimeter; a stirrer and a thermometer were included to mix the water and take its temperature and the whole calorimeter was enclosed in a large tin filled loosely with crushed paper to minimize heat loss (fig. 4). Carbon dioxide was run through the canister for fixed times at 200–300 ml/min. The temperature changes in the calorimeter were plotted against time until the maximum temperature rise had been recorded, and the calorimeter was cooling steadily. By extrapolating the cooling portion of the curve back to the time at which the carbon dioxide was turned off one could read off the rise of temperature caused by the carbon dioxide absorption; knowing the specific heats of water, the canister, the

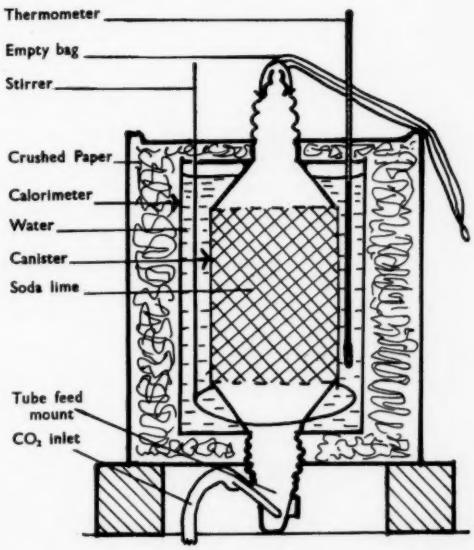

FIG. 4
Determination of total heat liberated during the absorption of a known amount of CO_2; the apparatus used (sectional view of calorimeter).

calorimeter, and the soda lime* the quantity of heat liberated can be calculated (fig. 5). Two well-known brands of anaesthetic soda lime were used in both the standard and the modified canisters. The flowmeter

* Determined by the method of mixture in water.

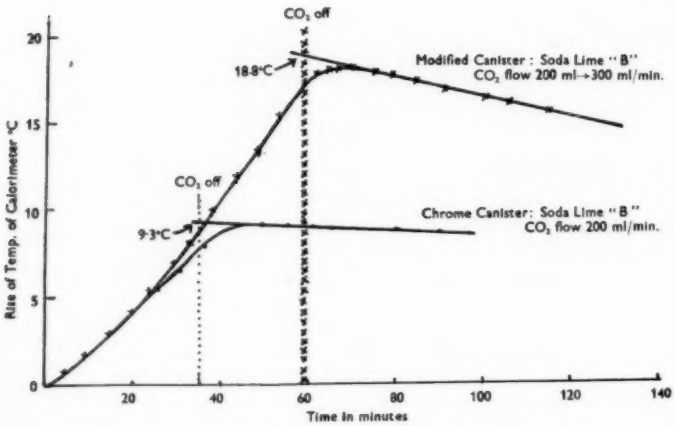

FIG. 5

Determination of total heat liberated during the absorbtion of a known amount of CO_2. The graphs show the rise and fall of the temperature of the calorimeter. Below is a specimen calculation to show how the rate of heat production is deduced.

Specimen Calculation.

Weight of canister: 633 g	Sp. heat brass: 0.094	∴ Water Equivalent	=	59.5 g
,, ,, calorimeter: 355 g	,, ,, zinc: 0.093	∴ ,, ,,	=	33.0 g
,, ,, soda lime "A": 485 g	,, ,, Soda lime "A" 0.310	∴ ,, ,,	=	150.5 g
,, ,, contained water: 700 g	.....	∴ ,, ,,	=	700.0 g
		∴ Total water equivalent	=	943.0 g

Maximal temperature rise (by extrapolation): 18°C.
Time of CO_2 flow: 63 minutes. Mean rate of CO_2 flow: 255ml/min.
∴ Total CO_2 flow was 63×255 ml.
Total heat produced was 943.0×18 cal.

∴ *Heat production was* $\frac{943.0 \times 18}{63 \times 255}$ cal/ml CO_2 = 1.16 cal/ml CO_2

was calibrated using a water displacement method. The results showed no significant difference in heat production between the two brands of soda lime.

The figure obtained was 1.18 ± 0.06 cal/ml carbon dioxide at 20°C.

This confirms the assumption that the chemical reaction can be expressed simply as above and that heat of solution is not a problem with modern soda limes, for any other chemical reaction likely to occur would result in the liberation of more heat than was in fact found and any heat of solution would be added on to this. These results also provide confirmation that the deductions made from the original cooling curves about heat dissipation are valid.

Heat dissipation from the surface, then, can easily be increased by blacking the surface; adding fins increases the dissipation further, probably by increasing both the radiating surface area and convectional loss.

HEAT MECHANICS OF CANISTERS WITH "RESPIRATORY" MOVEMENTS

The next questions are (*a*) does the modified canister remain cooler when used under clinical conditions, and (*b*) does the inspired gas temperature remain lower than with the standard canister? To answer these questions further experiments were undertaken as follows.

The canisters were connected up as if for clinical use (fig. 6). In place of the patient was an ordinary reservoir bag. "Respiration" was maintained by rhythmical compression of the reservoir bags alternately at 10–14 times a minute. The system was fully closed and free from leaks. Ordinary mercury-in-glass thermometers were used, but they are relatively slow to attain the temperature of their surroundings,

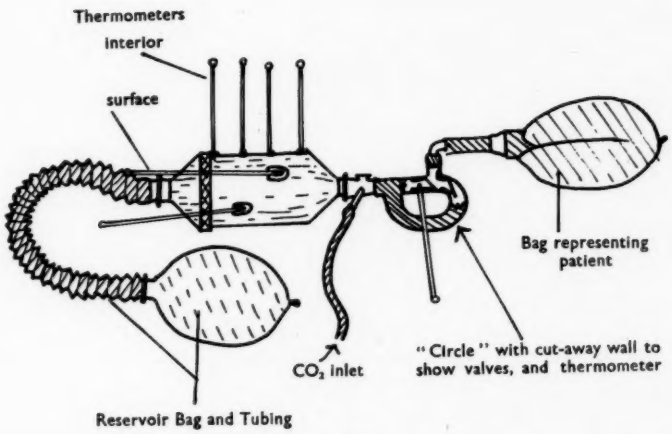

FIG. 6

Drawing of the apparatus used to investigate the heat mechanics of the Waters canister during CO_2 absorption with "respiration".

especially if these are gaseous; in order to get accurate readings a miniature "circle" system was constructed containing two one-way valves; a thermometer could be inserted just upstream of the inspiratory valve; the thick rubber walls of the "circle" conducted heat poorly so that, although it took four or five "breaths" for the inspiratory thermometer to reach its highest reading, the fall of temperature between "breaths" was small; if for some reason the inspiratory valve was incompetent this was immediately obvious in the rapid fall of the temperature reading during the expiratory phase. Without such an arrangement to separate the inspired air from the expired air the thermometer would merely record a mean reading between the true temperatures of the inspired and expired air. The system was filled with oxygen until one bag was full, the other being held empty. Then carbon dioxide was run in at 200 ml/min and "respiration" instituted. Surface and interior temperatures were noted at intervals until equilibrium was attained, which was in about 90 minutes. Then the "circle" and bag were removed from the front, the tube feed mount made gastight with plastic adhesive tape, the canister stood on end, and the reservoir bag, which was attached to the rear (now top) end of the canister, emptied completely and re-attached. The carbon dioxide inflow was continued but without any "respiration". Temperatures on the surface and in the interior of the canister were again noted until a second equilibrium, without "respiration", was reached; this took another 90 minutes or so. A comparison of the figures shows what effect the washing to-and-fro of gases caused by respiration has, and what sort of temperatures are reached in this apparatus with a carbon dioxide input similar to that which occurs clinically (table III).

TABLE III

Temperatures, in degrees Centigrade above room temperature, reached at equilibrium during absorption of CO_2 flowing at a known rate (approx. 200 ml/min).

	Standard canister					Modified canister					
	with "resp."			without		with "resp."			without		
	Surface temp.	Interior temp.	Inspired gas temp.	Surface temp.	Interior temp.	Surface temp.	Interior temp.	Inspired gas temp.	Surface temp.	Interior temp.	Room temp.
Expt. 1	18.4	29.5	15.5	40	58.3	17	22.2	14.2	26.5	38	21
Expt. 2	17.1	27.8	14.5	(>30)	(>45)	16.7	21.2	13.9	30	38.3	20
Means	17.7	28.6	15.0	—	—	16.8	21.7	14.0	28.2	38.1	20.5

"Respiration" was at about 5 litres/minute.
In Expt. 2 equilibrium without respiration was not reached.

When respiration stops, surface and interior temperatures rise, very quickly at first, to the sort of levels expected from earlier experiments. With respiration, however, the canisters remain much cooler, and the difference between them is very small—only about 6–7 per cent as regards surface temperature, and 7–8 per cent for inspired gas temperatures.*

*The interior temperature of the modified canister is, however, much lower than that of the standard one; this is explained by the fact that internal copper partitions had been fitted inside the modified canister in an effort to improve heat transmission through the soda lime to the surface—they were obviously effective in this. However, they had had no effect in reducing the inspired gas temperature; this meant either that the temperature of the soda lime had no effect on the inspired gas temperature, which seems absurd, or that the partitions improve conduction of heat to the gases passing through the canister as much as to the surface. Also note that the washing to-and-fro of the gases does not apparently assist in carrying heat from the interior to the surface, i.e. it does not act like stirring water, for the temperature gradient across the soda lime is the same both with and without respiration.

But of greater significance is the finding that *the inspired gas temperature never even approaches that in the interior of the canister, and under the conditions of these experiments remained well below body temperature.* The surface temperature seems to be a reasonable guide to that of the inspired gas, being 15–20 per cent higher; but the human hand is a poor estimator of temperature, for good conductors such as metals feel much hotter than poor conductors such as gases at the same temperature; a thermometer is the only reliable guide.

The effect of the fresh gas flow from the anaesthetic machine in reducing the temperature of the inspired gases has not been accurately determined; but experiments in which 2 litres/min and 1.3 litres/min flows of oxygen have been run in with the carbon dioxide suggest strongly that a flow of fresh gases at room temperature (Macintosh and Mushin, 1946), as in a closed-circuit-with-a-leak technique, does keep the inspired gas cooler (fig. 7). One would expect this to be so, and the lowering of the inspired gas temperature

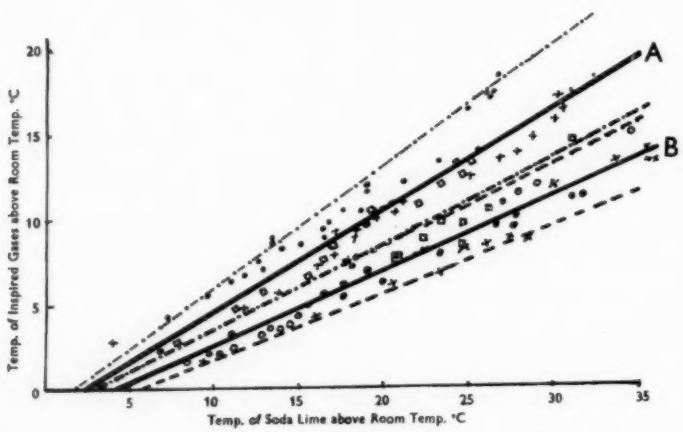

FIG. 7

Graphs showing the relation between inspired gas temperatures and soda lime temperatures with a CO_2 inflow rate of 200 ml/min approx., and a fresh gas flow of 1.3 litres/min—heavy line A,
2.0 litres/min—heavy line B.
The interrupted lines show the limits within which 95 per cent of the points fall. Each set of experimental figures is represented by a different symbol. Line A is the mean of four experiments. Line B is the mean of three experiments. The results with the two different fresh gas flows differ significantly from each other in spite of the small difference in fresh gas flow relative to the minute volume, which was about 5 litres/min.

to be governed according to the following expression:

$$\frac{T_{cl} - T_r}{T_f - T_r} = \frac{\text{Minute Volume}}{\text{Minute Volume} + \text{Fresh Gas Flow}}$$

where T_{cl} = Temperature of inspired gas in fully closed circuit;
T_f = Temperature of inspired gas with a fresh gas flow;
T_r = Room temperature.

Where, then, does the heat go during respiration? The possible routes of dissipation of heat are as follows:

(1) Surface radiation.
(2) Evaporation of water from the soda lime, which then condenses in the reservoir bag and tubing.
(3) Heating the soda lime itself and the canister (until equilibrium is reached).
(4) Cooling of the gases in the reservoir bag and tubing.
(5) Surface convection.

Considering these in order: (1) we have already determined; (2) can be measured by weighing the reservoir bag and tubing before and after use of the to-and-fro system, and also the canister as a check (see below); (3) can be calculated exactly; (4) the maximal heat loss by this route can be calculated by assuming that gas which passes from the canister into the reservoir bag and tubing is as hot as, or hotter than, the inspired gases (a few temperature readings taken immediately behind the canister confirm that this is so); (5) cannot be assessed on the present data.

Steps were taken, therefore, to estimate water evaporation from the canister (No. 2 route above) so that a heat balance sheet could be devised which would give an over-all picture of the heat mechanics of the canister during clinical use.

Determination of water evaporation.

The apparatus was set up exactly as in the previous experiments (fig. 6) after the charged canister and the bags and tubing had been weighed to the nearest 0.5 gram. Carbon dioxide was run in at 200 ml/min for 100 min, with "respiration" maintained at 10–14/min. The apparatus was then dismantled carefully, to avoid loss of water, and reweighed. The results of weighing the bags and tubing agreed well with those of weighing the canister, but since the canister was about twice as heavy as the bags and tubing and therefore any weighing error would have a greater significance, it was the increase in the weight of the bags and tubing which was taken as the true weight of water evaporated from the soda lime.

The results are tabulated below (table IV).

HEAT BALANCE SHEET FOR THE CANISTERS

It is now possible to construct heat balance sheets (table V) for the four experiments of table IV.*

This heat balance sheet shows clearly that heat dissipation from the surface is only a part of the total dissipation, about 35 per cent for the modified canister under the experimental conditions and 27 per cent for the standard canister. That occurring through cooling of the warmed anaesthetic gases is only about 8 per cent for the modified and perhaps 10 per cent for the standard canister; this explains the quite small effect on

*Heat lost by surface radiation was calculated as follows: a graph was drawn of surface temperature against time; the area under the curve is representative of the total surface heat dissipation; a geometrical mean surface temperature can be deduced, and from figure 2 the absolute heat dissipation in cals/min can be read off. A similar method is used to determine the maximal heat dissipation by cooling of the anaesthetic gases.

TABLE IV

Latent heat of evaporation of water at 46° C (temperature of soda lime) is 570 cal/ml.

	Experiment 1		Experiment 2	
	Standard	Modified	Standard	Modified
Water evaporated from canister ...	8.95 ml	11.4 ml	15.9 ml	13.4 ml
Heat dissipated in calories ...	5101	6499	9063	7638
Heat dissip. cal/ml CO_2/min ...	0.251	0.297	0.397	0.335

Mean heat dissipation : Standard canister : 0.324 cal/ml CO_2/min $\pm$ 0.073.
Modified canister : 0.316 cal/ml CO_2/min $\pm$ 0.019.

The flow rate of CO_2 in the experiments was 200 ml/min ; the flowmeter was calibrated by a water displacement method. The duration of the experiments was 100 minutes.

TABLE V
Heat balance sheet

Heat Production cal/min/ 100 ml CO_2		Heat dissipation cal/min/100 ml CO_2 (figures in brackets = % total heat production)			
		Modified 1	Standard 1	Modified 2	Standard 2
118	By CO_2 absorption	—	—	—	—
	By surface	42.5 (36%)	33.0 (28%)	40.3 (34%)	30.7 (26%)
	By water evaporation ...	29.7 (25%)	25.1 (21%)	33.5 (28%)	39.7 (34%)
	By heating of canister ...	6.9 (6%)	5.8 (5%)	6.6 (6%)	4.9 (4%)
	By heating of soda lime ...	14.1 (12%)	14.5 (12%)	15.9 (13%)	13.5 (11%)
	By anaesthetic gases ...	9.9 (8%)	13.2 (11%)	9.0 (8%)	9.1 (8%)
		103 (87%)	92 (77%)	105 (89%)	98 (83%)
	Balance	15 (13%)	26 (23%)	13 (11%)	20 (17%)
118		118 (100%)	118 (100%)	118 (100%)	118 (100%)
	Data for the calculations above				
	Geometrical mean of surface temperatures (°C)	32.4	35.6	34.3	36.9
	Room temperature (°C)	19.4	19.6	21.6	21.2
	CO_2 flow (ml/min)	221	203	228	228
	Time of flow (min)	99	100	100	100
	Water evaporated (grams)	11.4	8.95	13.4	15.9
	Geometrical means of gas temperatures (°C) ...	30.4	32.9	31.9	31.5
	Mean temperature of soda lime (°C)	41.0	39.6	46.6	42.8
	Weight of soda lime 'A', (grams)	460	474	470	460
	Weight of canister (grams)	1018	696	1018	696

inspired gas temperatures of increasing the surface heat dissipating power of the canister. Evaporation of water, however, is quite important, accounting for around 25 per cent or more of the total heat dissipation. The figures for heat spent in warming the soda lime and canister themselves are also quite considerable, being 15–19 per cent of the total in these experiments; the inflow of heat to the soda lime and the canister is greatest at the beginning and tails off gradually until equilibrium is reached, which takes 1½–2 hours. The proportion of heat not accounted for in the balance sheet can probably be ascribed to convection in part: experimental error must account for the rest; the temperatures will have tended to be underestimated.

CLINICAL OBSERVATIONS

The experimental results can be criticized on the ground that in clinical practice the gases expired by the patient are at body temperature, whereas in the experiments described they are at some temperature lower than that of the inspired gases, and this will tend to raise the temperature of the soda lime further and so raise the temperature of the inspired gas further. Therefore temperatures were recorded during a number of operations on unselected patients during routine general surgical lists using the Waters canister; interior and in some cases surface temperatures were noted, and the inspired gas temperature using the miniature "circle". The results obtained show that the inspired gas temperatures were very similar to those found experimentally, and rarely exceeded body temperature; they were related to the soda lime temperature as expected (fig. 8).

CONCLUSIONS

The heat mechanics of the Waters canister are quite complicated because under clinical conditions thermal conditions inside the canister are dynamic rather than static. But the picture of the working of the canister that has emerged seems to be as follows. During use carbon dioxide is absorbed by virtue of a chemical reaction which can be represented by the simple equation

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O + \text{heat}.$$

The heat produced by this reaction warms up

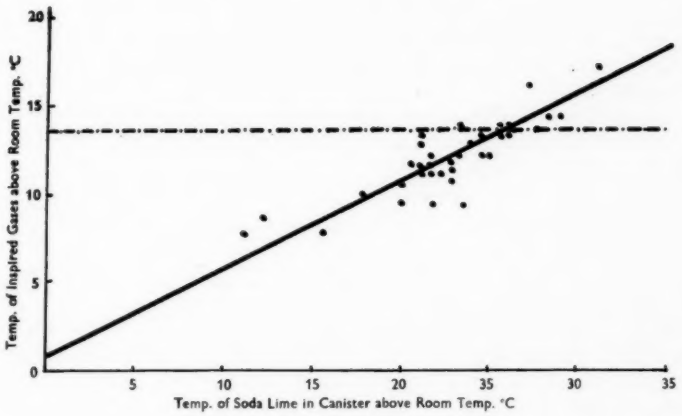

FIG. 8

Graph showing relation between inspired gas temperatures and soda lime temperatures during 20 unselected clinical anasthesias. Fresh gas flow rate 1.5 litres/min (three cases at 2.0 litres/min). The interrupted horizontal line represents body temperature when the figures are for a mean theatre temperature of 24.4°C=76°F.

the soda lime and the canister. It also heats the gases passing through the soda lime; but conduction of heat from the granules to the gas seems to be too slow for the gas to attain more than about half the temperature of the granules, so that the temperature of the inspired gas approaches, but rarely exceeds, that of the patient; we can say, therefore, that active heating of the patient *cannot* occur, and reflex effects from the warm gas are extremely unlikely. The main channels of heat dissipation are: first, surface radiation (and also, presumably, convection); secondly, evaporation of water from the soda lime which then recondenses in the bag and tubing; thirdly, warming of the soda lime and canister, chiefly during the first hour or so of use; cooling of the anaesthetic gases in the tubing and bag plays only a small part in dissipating the heat. Improving the radiating power of the canister alters to some extent the distribution of heat dissipation between the various possible channels, but has very little effect on the temperature of the inspired gases: the fresh gas flow does have some effect in reducing the inspired gas temperature. The washing to-and-fro of the anaesthetic gases caused by the patient's respiration plays a fundamental part in heat dissipation; it permits evaporation of water from the interior of the canister and produces some gas cooling, which between them account for some 35–40 per cent of the total heat dissipation.

The claim that the canister causes warm, moist gases to be supplied to the patient is fully justified. There is, however, no danger of the patient's respiratory tract, or general physiology, being damaged by excessively hot gases as some have feared. Neither is there any real danger of "heat retention", for heat loss via the lungs is only a small part of the total heat loss of the patient; other factors, such as a hot and humid theatre, rubber sheeting over the patient, and the use of atropine, are of importance in this connection, particularly in feverish patients.

Waters' canister seems, therefore, to have all the advantages claimed for it; from the point of view of its heat mechanics there is no indication for modifying it.

SUMMARY

The heat mechanics of the Waters canister have been investigated, and the ways in which the heat of reaction is dissipated elucidated. No evidence

has been found to suggest that the presence of a hot canister near the patient is in any way harmful, but rather the reverse. The heat liberated during carbon dioxide absorption has been measured directly, and the result confirms that the over-all chemical reaction is the conversion of $Ca(OH)_2$ to $CaCO_3$.

ACKNOWLEDGMENTS

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THE OESOPHAGEAL CARDIA AND REGURGITATION*

BY

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AN understanding of the mechanisms governing the integrity of the cardia is of immense importance to the anaesthetist. The cardia is intimately concerned with the vital problems of vomiting, regurgitation, and aspiration of gastric contents into the lungs, and the lethal potentialities of these complications are only too well known. If any proof be needed, the Report on Deaths Associated with Anaesthesia (Edwards et al., 1956), published under the aegis of the Association of Anaesthetists, reveals the serious menace of regurgitation and aspiration. There cannot be an anaesthetist who has not experienced trouble and anxiety—and often—from these hazards. This being so, it might be interesting to present various views and findings which relate to this problem.

Having referred to the importance of cardia, it may seem odd to say that it is doubtful whether, in point of anatomical fact, it exists at all. In 1719, Claude Helvetius, French philosopher and physician, described a sphincter—the so-called cardiac sphincter—at the gastro-oesophageal junction. Since then, despite the most careful search, nobody has been able to provide any concrete evidence of the existence of this anatomical sphincter, at least not in any demonstrable fashion. It has been curiously controversial —a few anatomists have agreed that there is a morphological sphincter, but the majority have denied it, and in the meantime many ingenious theories have been put forward to account for the undoubted sphincter-like function at the lower end of the oesophagus. The position today is only gradually becoming more clear than when Helvetius first described a cardiac sphincter. There does seem to be an obvious everyday need to postulate such a control. Regurgitation from stomach to oesophagus would be continuous if there were not some arrangement to resist the force of intraperitoneal and intragastric pressure.

The cardia is usually taken to mean the localized region at the junction of the oesophagus with the stomach. There is, however, no clear-cut demarcation between oesophagus and stomach, as the change from the squamous epithelium of the oesophagus to the columnar epithelium of the stomach may not correspond with the gross anatomical appearances. Normally, the cardia is within the abdomen, and in this position acts as a competent valve, but if the cardia be in the chest, as in sliding hiatus hernia, this competence is diminished. It would seem, therefore, that the functional efficiency of this "sphincter" is very dependent on its anatomical shape and position. The competence is such that, in the normal position, the cardia yields readily to quite low pressures on the oesophageal side, while it is able to resist pressures up to 80 mm Hg on the gastric side. Indeed, even in the cadaver, the cardia can usually be shown to be competent. The physiological mechanism for opening the cardia is by reflex, on the act of swallowing or by the arrival of a peristaltic wave at the cardia.

There are four main theories to account for the competence of the cardia to prevent reflux.

(1) The anatomical sphincter.
(2) The intrinsic, functional sphincter.
(3) The extrinsic, diaphragmatic pinchcock.
(4) The valvular mechanism, related to the oblique angle of entry of oesophagus to stomach.

(1) *The Anatomical Sphincter* was described by Helvetius as a circular thickening of muscle fibres around the oesophageal orifice, and this observation appears to have been repeated by others off and on over the course of the years. Lerche

* Based on a Presidential Address to the Scottish Society of Anaesthetists, April 1958.

(1950), an American writer, went so far as to describe two sphincters; but it is a strange fact that modern anatomists appear unable to find any such structure. From the practical standpoint, and in view of the historical disagreement on the subject, one can take it that there is no real sphincter in the anatomical sense.

(2) *The Intrinsic, Physiological Sphincter.* The following observations strongly suggest the existence of such a functional sphincter. First, even when the cardia is above the diaphragm in sliding hiatus hernia, some sphincteric activity can still be detected at the cardia. Second, with corrosive burns of the oesophagus the distal few centimetres tend to escape, which suggests protective spasm in this area. Third, achalasia of the cardia is said to be due to the inability to relax of an otherwise normal sphincter mechanism. Many patients with achalasia who have had a Heller's operation (division of the muscular coats down to the mucous membrane) subsequently develop symptoms of reflux. Finally, while experimental proof of an intrinsic functional sphincter has been elusive through the years, the most recent experimental data continue to favour such a concept. For example, quite recent contributions by Atkinson and Rowlands (1957) and Fyke et al. (1956) have demonstrated, by means of combined manometry and radiology, a zone of high pressure interposed between stomach and oesophagus. This pressure is consistently higher than the gastric pressure, and is said to be typical of a sphincter anywhere. Here is the paradox—a physiological sphincter without an anatomical sphincter!

(3) *The Extrinsic, Diaphragmatic Pinchcock.* This theory is perhaps the most intriguing, though no longer acceptable. It is based on the idea that during contraction of the diaphragm, the crura exert a gripping action on the distal end of the oesophagus, and so effect closure. It was thought that this was the reason why a barium swallow is delayed at the diaphragm during inspiration, a fact long recognized by radiologists, but a more satisfying explanation of this phenomenon will be given in a later paragraph. Professor P. R. Allison (1951), whose work on reflux oesophagitis is responsible for so much of the recent revival of interest in this subject, has stressed the importance of the sling-like action of the right crus of the diaphragm, which sweeps over the terminal oesophagus at the angle it makes with the stomach. Professor Allison supports the theory that, when the diaphragm contracts, this right crus exerts a pull which increases the angulation at the oesophago-gastric junction

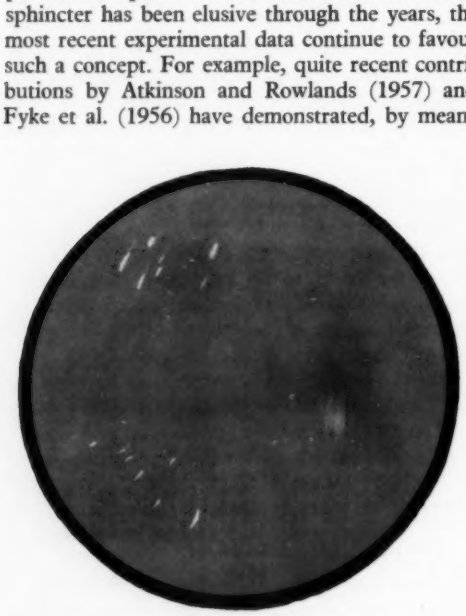

FIG. 1
The cardia as seen during quiet unobstructed respiration.

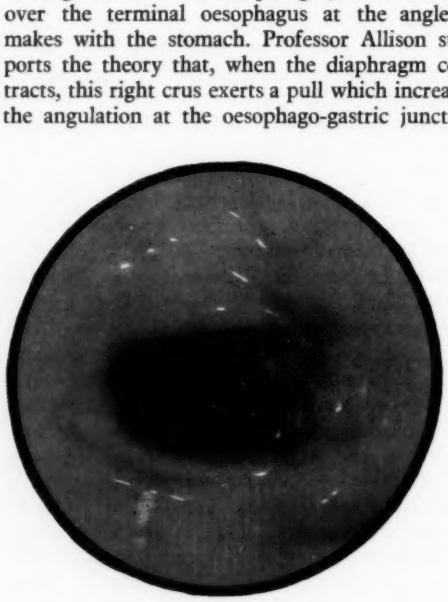

FIG. 2
The cardia seen opening widely with attempted inspiration during obstructed respiration.

and tends to close the lower end of the oesophagus. More recently Braasch and Ellis (1956), in an important experimental study on dogs, have shown that the distal segment of the oesophagus relaxes rather than contracts at inspiration. In point of fact, eructation and reflux occur only during inspiration, which would seem to contraindicate a pinchcock action. In this connection, on the occasions when one has been able to view this area for oneself through the oesophagoscope, it was found that, with the patient intubated with a well-fitting cuffed tube and breathing spontaneously, if one deliberately obstructed the respiration for a few breaths, the cardia could clearly be seen to open with attempted inspiration, in an obliquely linear fashion, or more widely. It was quite a definite and constant finding and is illustrated in the two coloured illustrations drawn from selected sequences from a cine-film shot via the oesophagus (figs. 1 and 2). This "opening" effect during obstructed inspiration was very striking, and one could clearly see the dangers of the accidental performance of this manoeuvre should the stomach be distended with fluid or the intragastric pressure high. It certainly gives the impression of a diaphragmatic pull, and suggests that contraction of the diaphragm actually opens the cardia rather than closes it—at any rate when respiration is obstructed. It is interesting to note that on direct examination at operation or via the oesophagoscope, neither a sphincter nor a valve can be identified, nor, during normal quiet respiration, can any cardiac opening be seen. The so-called "rosette" appearance described by some oesophagoscopists is probably no more than the slight narrowing of the oesophagus as it passes through the diaphragm.

(4) *The Valvular Mechanism* of cardiac competence is based on the oblique angle of entry of the oesophagus to the stomach. It is readily understood by reference to figure 3. The explanation of this valvular mechanism seems to be in the anatomical features, notably the acute or eccentric entry of oesophagus to stomach. The essence of this is that the intragastric pressure in itself will tend to assist closure. It is also suggested that an effective flap-valve is developed at the left lip of the oesophageal opening, and this is able to seal the cardia. These mucosal flap-valves have been observed in some animals and are said to be especially well developed in the guineapig. It seems likely that in the human subject, however, these flaps are functional rather than anatomical. Dornhorst et al. (1954) believe that the muscularis mucosae, which is well developed in the lower portion of the oesophagus, is able to pull the lax mucosa into a valvular form.

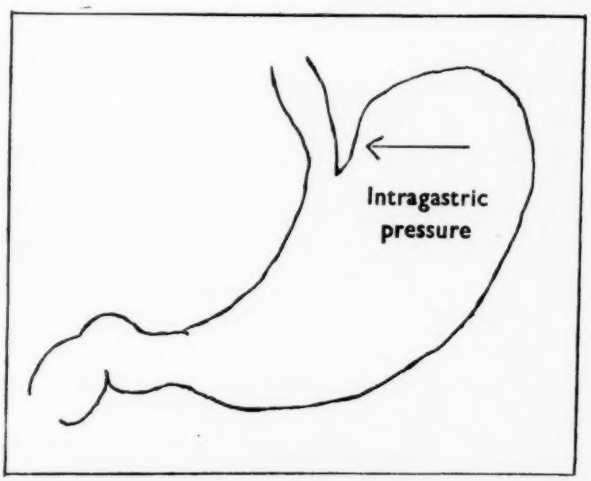

FIG. 3

Perhaps the most interesting of recent work on this subject comes from an essay by Paul Marchand (1954). Marchand showed the importance of the anatomical shape and position of the cardia by the following experiments on cadavers. He measured the intragastric pressures required to overcome the cardiac resistance under varying experimental conditions (fig. 4).

To go back now to the question of why a barium swallow is delayed at the diaphragm during inspiration. The barium flows quite freely during expiration, but on inspiration there is a delay at the cardia, while the oesophagus just above this level dilates up into a temporary bulge. This is called by the radiologists the "phrenic ampulla", and is a constant and normally occurring rhythmical dilatation and delay during inspiration.

The suggestion was that diaphragmatic pinching was responsible. A better explanation is that, with the difference of pressure ordinarily developed between thorax and abdomen during inspiration, this pressure differential could in itself be quite sufficient to account for any delay. On deep inspiration the negative pressure in the pleural space becomes more negative, while the positive pressure in the abdomen becomes more positive, and these pressures are transmitted directly to the oesophagus and stomach. In other words, at the end of inspiration there is a high pressure in the stomach and a low pressure in the oesophagus. One can readily see that such a pressure differential would constantly tend to produce regurgitation, but normally this is easily resisted by the competent cardia. However, with obstructed respiration, or with an already distended stomach, or both, it is quite another matter as very high pleuroperitoneal pressure

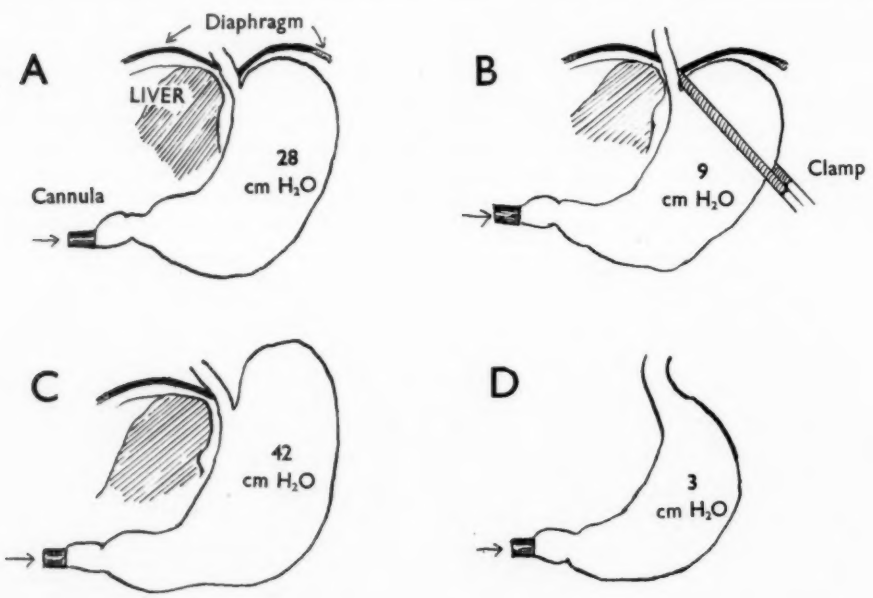

FIG. 4

A Control—normal anatomical relationships. Pressure required = 28 cm H_2O.
B Fundus clamped off, abolishing normal gastro-oesophageal angle. Pressure required = 9 cm H_2O.
C Left leaf of diaphragm removed, allowing fundus to bulge into chest and making exaggerated gastro-oesophageal angle. Pressure required = 42 cm H_2O.
D Liver and both leaves of diaphragm removed, rendering the cardia almost incompetent. Pressure required = 3 cm H_2O (Marchand, 1954).

differences are set up. A glance at figure 5, taken from Dornhorst (1954), shows this quite clearly.

Reference has already been made to this pleuroperitoneal pressure gradient as being a force constantly tending to favour regurgitation, especially during inspiration. This is exactly the means by which cows ruminate, or chew the cud. From time to time they inspire happily against a closed glottis and quietly regurgitate the ingesta back into the mouth. Veterinary surgeons say that a cow with a tracheotomy opening has the greatest difficulty in regurgitating at all. Theoretically at least, therefore, a preliminary tracheostomy would presumably lessen the chances of regurgitation and aspiration under anaesthesia. Some people with sliding hiatus hernia are, of course, ruminants too, because of the ease with which they regurgitate—and by the same mechanism of inspiring against a closed glottis.

There is a further anatomical point of practical concern to the anaesthetist. The lower half of the oesophagus is composed of unstriped, involuntary muscle, while the upper half is composed of striped muscle. Muscle relaxants, therefore, have no effect on the cardia and lower oesophagus, but, on the other hand, curare does relax and paralyze the upper oesophagus and the cricopharyngeal sphincter. In fact, vomiting and regurgitating should probably be regarded as a two-stage affair. Firstly, the cardia is overcome and stomach contents fill the oesophagus—and the oesophagus can hold a surprising volume of fluid, as much as a pint. Secondly, the cricopharyngeal sphincter relaxes and the fluid may then reach the pharynx and mouth, or even the air passages and lungs. In intestinal obstruction, for example, fluid may be already lodged in the oesophagus but only visibly regurgitated when the cricopharyngeal sphincter is relaxed. This relaxation of the cricopharyngeal sphincter occurs relatively early and suddenly when muscle relaxants or intravenous anaesthetics are used. In the case of inhalation anaesthesia the relaxation is more gradual, and this is really the basis of the safety of the straight "gas–oxygen–ether" technique, which frowns on the use of muscle relaxants or intravenous anaesthetics until the trachea is safely intubated with a cuffed tube.

It should be realized that regurgitation, unsuspected and covert, is possibly a lot more common than one may appreciate. Culver and Beecher (1951) in America investigated the incidence of regurgitation and aspiration in 300 unselected surgical patients, and Weiss (1950) did the same

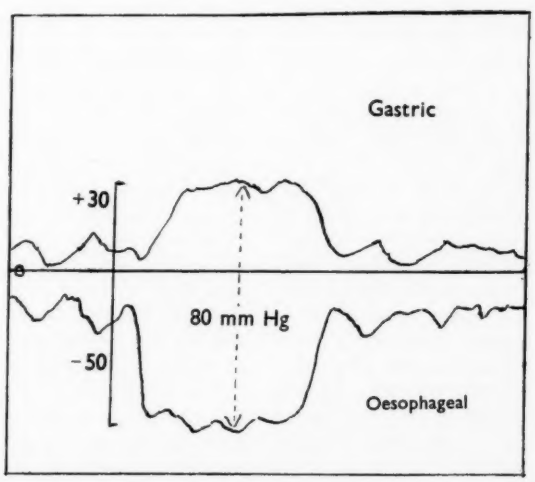

FIG. 5
Müller's manoeuvre. Inspiration against a closed glottis (Dornhorst, 1954).

with 112 cases. The technique of investigation was the same in both cases. A capsule containing 4 ml of 0.25 per cent Evan's Blue dye was swallowed with a little water half an hour before induction of anaesthesia. The anaesthetic was thiopentone, nitrous oxide, oxygen, ether. At the conclusion of the operation the pharynx, larynx, trachea and main bronchi were examined for the presence of the blue dye. The results were striking and in the two series agreed so closely that it will be sufficient to summarize the figures. Very briefly, 25 per cent of the cases regurgitated to the pharynx, and in 19 per cent of the cases the dye was seen below the larynx. It would seem, therefore, that in nearly one case in every five, during routine surgery and in the absence of frank vomiting, fluid stomach contents find their way into the lungs. If the dye was found below the larynx at all, it was most commonly seen in both the trachea and right main bronchus. Two further interesting points emerge from these figures: (*a*) that the incidence of aspiration to the bronchi was not markedly less when an endotracheal tube (presumably uncuffed) was used; (*b*) that the over-all incidence of regurgitation was 22 per cent with an experienced anaesthetist and 30 per cent with an inexperienced anaesthetist.

It might be of interest to discuss a few points on the practical anaesthetic management of the typical case which might give trouble, the surgical patient with intestinal obstruction. First of all let us remind ourselves of the factors which aggravate gastric retention—pain and anxiety, circulatory collapse, salt depletion, morphine, food and drink, and reverse peristalsis. All these factors should be considered and dealt with as best as may be.

With regard to premedication, perhaps morphine and such drugs are best withheld altogether from these patients and atropine alone given, as the following case illustrates. This was a man, aged 60 years, whose abdomen was much distended but who had not been vomiting. He was described as being apparently in reasonably good condition, and morphine 15 mg with atropine 0.6 mg was ordered. Half an hour later, while the patient was still in the ward and before even a gastric tube had been passed, he regurgitated, asphyxiated, and died. It is suggested that he might well have coped with this incident had it not been for the morphine.

Pre-operative gastric suction in these cases should preferably extend over an hour or two, either continuously or intermittently. The on-shot suction effort is hardly adequate. Recently the writer has been using a No. 12 gastric tube with an inflatable cuff in the oesophagus. Although, of course, the idea of blocking the oesophagus is not new, it was thought that a tube for the combined purposes of routine gastric aspiration and oesophageal blocking at the time of induction would be advantageous. Such tubes were made on request by M.I.E. Ltd. The tube is passed into the stomach in the ordinary way for pre-operative suction, and the cuff is inflated to block the oesophagus just immediately before induction of anaesthesia. Once induction is completed and a cuffed tube is in the trachea, the oesophageal cuff is deflated. The cuff is situated in the middle of the tube, i.e. 15 inches from either end. In use the cuff should lie about the middle of the oesophagus, or at a level in the oesophagus corresponding to just below the bifurcation of the trachea. It is inflated with 10 ml of air. The oesophagus is very distensible, and the risk of damage with this cuff seems remote. One or two patients have complained of slight substernal discomfort but mostly there is no discomfort at all, and there has been no damage following use of the tube.

It seems quite as logical to block the oesophagus in order to prevent stomach contents coming up, as to block the trachea to prevent stomach contents going down. The withdrawal or even change of position of a gastric tube should be avoided while the patient is unconscious, as the movement of the tube through the oesophagus moves the loose mucosa and favours regurgitation. Another little point worth remembering is that giving the patient a mouthful of water to swallow just before induction of anaesthesia helps to empty the oesophagus—a useful safety device.

The actual induction of anaesthesia is probably best carried out on the operating table, and in the head-up position to seek the assistance of gravity. Suction apparatus must, of course, be to hand. It is a matter of individual preference which anaesthetic agents are used, but it is certainly a mistake to think that anaesthesia must almost

necessarily be induced with thiopentone, come what may. As an alternative, half a dozen or so breaths of cyclopropane mixture followed by a relaxant is about as quick and on the whole safer. A straightforward "gas–oxygen–ether" induction without relaxants until after the trachea is intubated also has its advocates. It has already been pointed out that the safety of this method depends upon the ability of the anaesthetist to intubate the trachea under light anaesthesia and before the cricopharyngeal sphincter has relaxed.

It is obviously better to try to prevent aspiration of fluid into the lungs than to have to cope with this mishap after its occurrence. When, however, fluid has entered the air passages, the effectiveness of bronchoscopy as a resuscitative measure may be disappointing—not, of course, the immediate bronchoscopy necessitated by a massive flooding, but rather bronchoscopy after the inhalation of relatively small amounts of acid stomach contents. In this event, bronchoscopy may serve only to increase the spasm, and simple suction with a soft rubber catheter through the endotracheal tube may in the end be just as effective and is less disturbing.

SUMMARY AND CONCLUSIONS

The present accepted concensus of opinion regarding the modus operandi of cardiac competence may be summarized as follows. The greatest stress is laid on the eccentric angle of entry of the oesophagus into the stomach, and the flap-valve formed at the left lip. In addition, there is almost certainly a truly inherent activity at the cardia, which has the physiological characteristics of a sphincter. The diaphragm is not thought to have any part in maintaining cardiac competence, and indeed overaction of the diaphragm can result in incompetence. There is certainly no demonstrable anatomical sphincter. The pleuroperitoneal pressure differential is a force constantly tending to favour regurgitation. Finally, inspiration against a closed glottis opens the cardia, thus making regurgitation most likely. All of which brings us back—as so often happens—to that most basic and fundamental of all anaesthetic principles—keep a clear airway and never allow obstructed respiration.

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THE MEASUREMENT AND RECORDING OF TEMPERATURES DURING HYPOTHERMIA

BY

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HYPOTHERMIA appears to have a definite place in surgery, and the production and control of this state is often the responsibility of the anaesthetist. It is, therefore, important that he should be familiar not only with the means by which cooling may be achieved, about which much has been written, but also with methods of measuring the temperature.

The concept of "body temperature" whilst adequate for most clinical purposes, is not sufficiently precise for induced hypothermia, where there may exist considerable differences in temperature between various parts of the body. Since cardiac arrhythmia, the factor limiting the degree of cooling, appears to depend on the temperature of the heart itself, it seems logical to try and measure this temperature. The careful work of Cooper and Kenyon (1957) has shown that the temperature measured in the oesophagus at heart level is very close to that in the aorta which may, however, differ from the rectal temperature by two or three degrees centigrade.

These considerations should be borne in mind when deciding on the site at which temperature is to be measured. The site, in turn, will influence the method to be adopted.

Though an indicating instrument is adequate in many situations, a recording device which will plot temperature against time is clearly desirable. At present accurate recording thermometers suitable for use in the operating room are expensive and not generally available; hence most anaesthetists will have to make do with simpler apparatus.

Whilst mercury-in-glass thermometers are most frequently used to measure temperatures in the range 20°C to 40°C there can be certain objections to their use in surgery.

If a patient's rectal temperature is measured in this fashion there is some risk of the thermometer breaking when the patient is moved. In addition, it may prove inconvenient to read the thermometer regularly. The rigid construction of the mercury-in-glass thermometer also prohibits its use for taking oesophageal temperatures.

Some of these disadvantages may be removed by the use of a mercury vapour thermometer. In this type mercury vapour is contained in a bulb connected to a Bourdon pressure gauge by means of a length of capillary tubing. The vapour pressure changes with alterations in temperature and the dial of the gauge is calibrated in degrees. Readings may now be taken at a point distant from the site of the bulb, but the system is non-recording.

Although recording mercury-in-glass thermometers are made (Cambridge Instrument Co., 1935) they record on photographic paper and are not generally encountered in medical practice. Some form of electrical temperature measuring system is commonly used and is essential when a recording is to be taken. The actual choice of a method depends upon the position at which the temperature-sensitive element is to be placed, and also upon what is available in the way of recording equipment.

The three commonly used systems are the Electrical Resistance Thermometer, the Thermocouple and the Thermistor Bridge. Each of these will now be discussed in detail.

THE ELECTRICAL RESISTANCE THERMOMETER

In principle, any property of a substance which is temperature-dependent can form the basis of a thermometer system. For example, when a metal wire is cooled its electrical resistance decreases progressively as the temperature is lowered. The wire is made to form one arm of a Wheatstone

bridge network which is balanced at some given temperature. If the wire coil is mounted in a suitably shaped probe it can be used to measure rectal or oesophageal temperatures. The alteration of the wire resistance with changing temperature causes the bridge to become unbalanced.

For the case where electrical recording is not required, the change in wire resistance is measured directly and converted into temperature change, using a previously prepared calibration curve. The changes in resistance encountered are small, and the simple Wheatstone bridge is not sufficiently sensitive to determine them accurately. For resistance thermometer work some form of slide wire bridge is used (Mitton, 1948), or a sensitive ohmeter circuit.

In order to obtain a reproducible calibration a pure metal wire must be employed. Normally it has a resistance of a few ohms, and platinum, copper or nickel are used. The leads connecting the thermometer coil to the bridge may have a resistance which is significant compared with that of the coil. To prevent changes in lead resistance with changes in ambient temperature from affecting the bridge balance, an additional dummy set of leads is used. These are identical in construction with the true leads and are included in the opposite arm of the bridge to the true leads. Any change in the bridge balance due to one set of leads is thus automatically cancelled out by a similar change in the opposite set.

When a bridge network becomes unbalanced, a voltage is developed across the terminals of the detector. This voltage is a function of the temperature change. With suitable amplification it can be made to operate a pen recorder.

Although it is not in general use in this country, the multi-channel recording equipment manufactured by the Sanborn company of America can be readily used for recording temperature as well as other parameters. With the Sanborn pre-amplifier Type 150-1100 a 3-ohm copper coil is used as one arm of an A.C. bridge energized at 2,400 c.p.s. The system has worked well during experiments with dogs undergoing hypothermia.

Alternatively, the out-of-balance voltage appearing across the bridge detector can be applied to a simple servo system. A motor driven potentiometer is arranged to develop a voltage which is equal and opposite to that appearing across the detector. The rotation of the potentiometer slider is thus proportional to the voltage and hence to the temperature change, and is made to actuate the recording pen.

The resistance thermometer coil can be mounted into a rectal or oesophageal probe (Soderstrom, 1933), but because of its size, it is not suitable for use with the fine probes needed for neurosurgical work.

THE THERMOCOUPLE

If two wires composed of different metals are joined end to end to form a closed electrical circuit, a current will flow in them when the two junctions are maintained at different temperatures. Such a circuit constitutes a thermocouple.

The current flows as a result of the thermal electromotive force which has been developed, and this e.m.f. depends upon the temperature difference of the junctions. If one junction is kept at a constant reference temperature, the thermal e.m.f. can be used as a measure of the temperature of the second junction. Precautions to be taken to avoid unwanted thermal e.m.f.s which may arise are given by Burton (1948).

Suitable combinations of wire materials for use in hypothermia are copper and constantan, or iron and constantan. Constantan is an alloy consisting of 60 per cent copper, 40 per cent nickel, developed for making standard resistors.

With one junction kept at 0°C and the second at 38°C, a copper constantan thermocouple will generate an e.m.f. of some 1.5 millivolts. This order of voltage can be measured directly with a sensitive galvanometer. Compact commercial instruments are available. A reflected light beam is used as a pointer and the instrument scale is calibrated directly in temperature. A description of a thermocouple meter and a resistance thermometer is given by Hartmann & Braun Ltd. (1950).

For greater accuracy, the e.m.f. of a thermocouple may be measured with a standardized precision potentiometer (Starling, 1947). In this type of instrument the voltage measured is referred to a Weston cadmium-mercury standard cell whose e.m.f. is accurately known.

Krog (1954) has discussed the design of needle thermocouples. Providing that the same reels of wire are used in the manufacture of a batch of

thermocouples very reproducible results can be obtained from couple to couple.

The graph of e.m.f. versus temperature for a copper-constantan thermocouple is practically a straight line over the range 18°C to 40°C. Recorders for use with thermocouples are in everyday use, but recording from a thermocouple presents some difficulties. Ten years ago it was not possible (Burton, 1948). The small D.C. voltage generated by the thermocouple is usually converted into an A.C. voltage by means of a vibrator (Dauphinee and Woods, 1955). This is stepped up by a specially designed transformer and amplified by an amplifier tuned to the vibrator frequency. A typical modern example of this type of amplifier is the Sanborn Model 150-1500 low level pre-amplifier.

The output of a thermocouple may also be fed directly into the input of a continuously self-balancing potentiometric pen recorder (Coombes and Hinderwell, 1950). This type of recorder is very widely used in industry and has a chart width of some 10 inches. Full scale sensitivities of down to half a millivolt are available.

Another form of amplifying system in current use with thermocouples for hypothermia is the "D.C. Amplifier and Microvoltmeter" manufactured by Messrs. Pye Ltd. (Banner, 1958; Cooper and Kenyon, 1957). The output from the thermocouple is applied to a conventional galvanometer which carries an additional "pick-up coil". This coil rotates in an alternating magnetic field which induces an A.C. voltage in the coil. The coil voltage is amplified and fed into a panel meter and recorder. Some of the voltage is fed back to the thermocouple galvanometer as a negative feedback such as to reduce the original deflection. This ensures that the gain of the whole system is very stable.

THE THERMISTOR BRIDGE

A thermistor consists basically of a semiconductor material which is characterized by having a large negative temperature coefficient of resistance (Sillars, 1942). Thus if it is cooled its resistance will increase and, because the change in resistance is large, a simple Wheatstone bridge will suffice. The thermistor material is usually a mixture of nickel, manganese and cobalt oxides.

A thermistor bead embedded in the wall of a glass envelope, e.g. the Standard Telephones and Cables Ltd., Type F, forms a convenient basis for the construction of a rectal or oesophageal probe.

Miniature bead thermistors such as the Mullard VA 2100 series are available. With care we have mounted them in 20 B.W.G. hypodermic needles of approximately 0.030 inch internal diameter. For the smallest needle probes, however, a thermocouple must be used.

A suitable bridge circuit is shown in figure 1. It is similar to that of Brummeter and Fastie (1947). The bridge detector meter can be switched with switch S_2 to check that the bridge

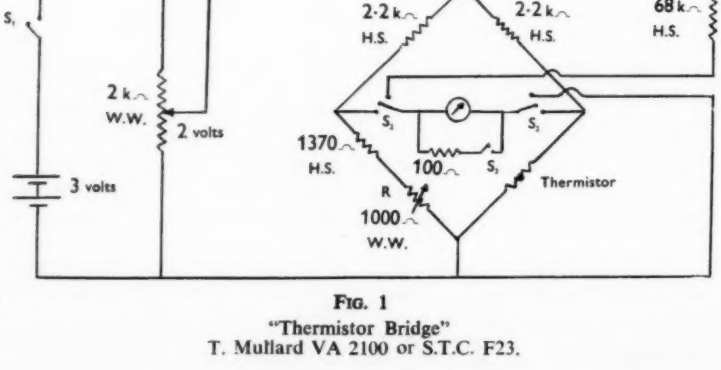

FIG. 1
"Thermistor Bridge"
T. Mullard VA 2100 or S.T.C. F23.

supply voltage is constant at 2 volts. Rheostat R is calibrated directly in degrees from 22°C to 40°C. As a safety precaution, switch S_3 shunts the meter until the final balance is made. The thermometer is conveniently calibrated against a good quality mercury-in-glass thermometer suspended in a circulating water bath.

The usual manufacturing tolerances on the resistance of thermistors are ± 20 per cent at a given temperature. If it is desired to use two probes with a particular apparatus a pair of thermistors with matched resistance/temperature characteristics must be obtained from the manufacturers.

Differences in the characteristics of individual thermistors can be a source of inconvenience when it is required to use a large number of probes with one measuring apparatus. Bleakley (1951) and Maclean (1954) have suggested a circuit modification to minimize this effect.

As in the case of the electrical resistance thermometer, the out-of-balance voltage appearing across the bridge detector may be amplified and used as a measure of the temperature change. A high gain stability D.C. amplifier is needed and for this purpose an amplifier such as the Sanborn A.C.-D.C. pre-amplifier type 150-1000 is suitable.

A simple self-contained recording thermistor thermometer has been described by Melville (1958). The thermistor is used in an A.C. bridge energized at 50 c.p.s. The 50 c/s voltage appearing across the bridge detector is amplified with a three-valve amplifier using considerable negative feedback and operates a pen recorder.

The need for better methods of temperature measurement and recording during hypothermia is becoming apparent. Instruments are now available for this purpose, but they are usually rather complicated and expensive when a recording is required.

SUMMARY

The advantages of electrical methods of measuring temperatures during hypothermia are described. The electrical resistance thermometer, thermocouple and thermistor bridge are treated in detail, and the suitability of each system for various kinds of probe is discussed. The possibilities of recording the temperature changes on a chart recorder are examined for each system.

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EPIDERMOLYSIS BULLOSA: A RARE DISEASE OF ANAESTHETIC INTEREST

BY

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THE purpose of this paper is to discuss the difficulties encountered in anaesthesia in epidermolysis bullosa. Various techniques have been used in the case described. All these have had their disadvantages. However, they do indicate that such cases may be anaesthetized with success. No claim is made that any one method is ideal.

In view of the rarity of this condition, it may be of interest to review briefly some aspects of its clinical features, aetiology, pathology and treatment.

CLINICAL FEATURES

Epidermolysis bullosa is a rare, chronic, hereditary disorder which affects structures of epidermal origin. It exists in two main types, simplex and dystrophic, but several subtypes are also known to occur. The prominent feature of this disease is the appearance of bullae which often arise as a result of slight trauma (Cockayne, 1933). Bullae may, however, arise spontaneously and in all cases are initially sterile. They contain clear or blood-stained fluid according to the degree of trauma and may become infected.

Epidermolysis bullosa simplex.

In this type of the disease the bullae are usually confined to the hands and feet, because these parts are more frequently subjected to trauma. They may be present at birth or appear within the first few years of life. Healing of the affected areas takes place without cicatrization. The mucous membranes are not affected and the teeth, hair and nails are normal. The general health is usually good and the tendency to bullae formation retrogresses towards puberty.

Cockayne (1938) describes a more localized form of epidermolysis bullosa in which formation of large bullae is restricted to the inner and outer aspects of the soles of the feet. They usually only arise in association with warm weather, give a sensation of heat and discomfort and are first noticed between the ages of one and two years.

In World War II, Waisman (1944) described another localized form. This affected the hands and feet after heavy manual activity or long marches and necessitated discharge from the fighting forces.

Epidermolysis bullosa dystrophica.

The manifestations of this type are more severe. Besides occurring in the skin, bullae are found arising in the mucous membranes, and abnormalities of the teeth and nails may be present. Several subtypes are recognized depending on the severity and mode of transmission.

Recessive forms. There are several types, all of which manifest a recessive inheritance (Newcomer, Zeilegna and Stemberg, 1956) and usually cause death before puberty. Those who suffer from these forms of epidermolysis bullosa are usually underdeveloped and mentally subnormal, but some of them reach adult life and have children. The bullae are larger than in the simplex type and are deeply situated. They are usually present at birth (fig. 1) but their appearance may be delayed until the child is one or two years old. Bullae formation may occur in the oral cavity, oesophagus, upper respiratory tract, genito-urinary tract and conjunctiva. The teeth are absent or deficient in number, in which case they are subect to decay because of defective enamel. The nails are invariably absent or deformed and growth of hair may be disturbed. Formation of scars and epidermal cysts is common.

Herlitz (1934) described the most severe form of this group under the term epidermolysis bullosa hereditana letalis. This occurs at birth or

shortly afterwards. The bullae involving the skin and mucous membranes become so extensive that death occurs at the age of three months. Often, blood and tendons may be clearly seen under the denuded areas, especially at the extremities. It is rather strange that trauma such as nipping or rubbing does not give rise to bullae formation. A positive Nikolsky's sign is present, however, which is demonstrated by the easy removal of the upper epidermal layers on slight pressure. Dystrophy and deformity of the nails may be evident. Some of them may be absent at birth or fall off soon afterwards. If the lesions are progressive they may give rise to skeletal atrophy of the terminal phalanges.

Dominant form. This is classified as a separate type whose severity is intermediate between the dominant simplex and recessive dystrophic forms. The teeth and hair are normal and the majority of patients are well developed. The nails may be absent but are usually greatly thickened and clawlike. Bullae, due to trauma, occur at birth or soon afterwards and are particularly prominent in the forehead and extremities. They heal with the formation of atrophic scars. Epidermal cysts and milia are common in the vicinity of the scars. The mucous membranes are involved but to a lesser extent.

AETIOLOGY

This is highly speculative but a common theory of Engman and Mook (1906) is based on the finding of a definite deficiency of elastic tissue in the papillary and subpapillary layers of the cutis in both the normal areas and those affected by the bullae. This deficiency is thought to account for the susceptibility of the epidermis to bullae formation following trauma. In many cases, however, the quantity of elastic tissue is said to be normal.

Others (Winer and Orman, 1945) suggest that there is a primary inherited defect involving the permeability of the vessel walls. This permits transudation of serum into the upper layers of the epidermis with consequent production of bullae. The destruction of elastic tissue is attributed to the resulting oedema.

PATHOLOGY

In the simplex type, the bullae usually occur within the epidermis and heal without scar formation. The elastic tissue is frayed and splintered but not destroyed. In the dystrophic type the lesions occur in the subepidermal tissues with scar formation and considerable destruction of elastic tissue. Mild inflammatory changes may be evident in the cutis.

DIFFERENTIAL DIAGNOSIS

Diagnosis has to be made from conditions such as dermatophytosis, blisters, pemphigus neonatorum, congenital syphilis, bullous erythema multiforme, pemphigus vulgaris and porphyria congenita.

TREATMENT

No satisfactory treatment has been described. The treatment at the present time is with a.c.t.h. or cortisone, but the results have been disappointing. The rapidity with which bullae appear and the slight trauma required for their production provide many nursing problems.

In infants, bullae arise through scratching the body or rubbing the hands, heels or head on the bedclothes. The lesions on the arms and legs may be prevented to some extent by fastening the limbs to the side of the cot. Unfortunately bullae develop beneath the restraining bandages but are less severe if the bandages are applied over layers of vaseline gauze and cotton wool.

The feeding of an infant is often initiated by slight pressure of a teat on the dorsum of the tongue (fig. 2) This rapidly leads to bullae and scar formation at this site and makes the child reluctant to feed. Tube feeding, instituted to overcome this disability, leads to lesions in the nasopharynx and around the nares which soon become infected. Trauma due to repeated insertion of the oesophageal tube may be minimized by maintaining it in position. This requires the application of strapping to the face. When the strapping is removed, the underlying bullae or raw areas are evident.

These are only a few of the difficulties which have to be solved. Innumerable problems arise, however, and they tax the skill and ingenuity of the nursing staff to the utmost.

Similarly it is readily apparent that the anaesthetist, when confronted with such a case, will also have many difficulties to overcome as may be seen in the following case history.

CASE HISTORY

In a family of four, the patient, his brother and younger sister showed manifestations of epidermolysis bullosa. The elder sister had no skin disorder but had suffered from eczema in infancy. The parents appeared to be free from the disease, but asthma and eczema were evident in the family of the maternal grandmother.

The patient first developed blistering of the legs and hands shortly after birth. Healing left bluish scars and blackened finger nails.

Three years later, there were two episodes when he coughed up blood after a bout of crying. These were followed by a slight haematemesis and another haemoptysis. The mother complained that "he was always crying, easily upset, touchy and nervous". He was worried about his rash and frequently remarked that he wished it would get better.

The blood picture, including clotting and bleeding times, was normal. No cause was found for the haemoptysis or haematemesis.

During the past three years, the patient attended hospital for dental treatment and the problem of anaesthesia was approached differently on each of three occasions.

He was first anaesthetized for teeth extraction by means of a naso-oral inhaler. As a result of this appliance, he developed severe blistering of the mouth, face and nose.

When he again attended for treatment, it was decided, in view of his past history, to attempt conservative dentistry and his teeth were filled without anaesthesia. He was unco-operative and developed multiple bullae on the limbs from the restraint applied by the attendants.

Recently he was found to require further fillings and the extraction of several teeth. In view of his past experience, it was obvious that he would not tolerate a similar procedure, even under local anaesthesia.

His mother was equally concerned about the prospect of him having a general anaesthetic as both her sons had developed bullae through "fighting when coming out of the anaesthetic".

In avoiding these complications, the only satisfactory way of maintaining anaesthesia for dental fillings and extractions was by endotracheal intubation. Although there is no record of bullae occurring actually within the larynx in this condition, the possibility appeared likely, as they have been described in the upper respiratory tract and the oesophagus. Because of this danger, it was decided to insert an endotracheal tube of narrow bore so that contact with the larynx would be avoided as much as possible. Some of the problems which arose in using this technique will be described.

The boy was reassured pre-operatively and given atropine 0.6 mg subcutaneously.

He was induced with thiopentone 75 mg which was followed by suxamethonium 20 mg intravenously. His lungs were then inflated with the face mask applied as gently as possible until relaxation had occurred.

As he was seven years of age, he would normally have tolerated a number 4 Magill's endotracheal tube. In order to avoid direct contact with the laryngeal opening, a number 1 Magill's endotracheal tube was lubricated and gently inserted into the larynx.

Application of strapping to the face, in order to fix the tube in position, was avoided in order to prevent bullae formation. The tube was partially secured and kinking prevented by the gentle insertion of an oiled mouth pack. During the operation the tube was steadied by the assistant. Anaesthesia was maintained by 7 litres of nitrous oxide, 3 litres of oxygen and a trace of trichloroethylene. The gas flows were sufficient to avoid carbon dioxide build-up and to maintain anaesthesia by avoiding excessive dilution of the inhalant gases by influx of air around the tube.

The dental fillings were completed first to avoid obscuring the field with the bleeding arising from the extractions and also to prevent inhalation of blood past the loose throat pack. Because of this danger and the discrepancy between the size of the endotracheal tube and the laryngeal aperture, the extractions were performed with the patient in the head down position. Care was taken that no unnecessary movement of the head ensued during the operation in order to avoid laryngeal irritation.

This boy developed bullae on the inside of the lips and mouth due to the intra-oral surgical manipulation but did not develop stridor which suggested that there had been no laryngeal trauma.

DISCUSSION

Anaesthesia in epidermolysis bullosa necessitates the avoidance of trauma to the skin and mucous membranes. In severe cases bullae will arise on the slightest contact (figs. 3 and 4). It is obvious that the lesions cannot be completely avoided but their severity may be minimized.

The mother's description of the boy's nervousness suggests that premedication should be adequate. It is probably unwise to prescribe barbiturates such as quinalbarbitone because of the possibility of postoperative hallucinations, especially if pain is present. Rectal thiopentone may be useful in operations of longer duration. Chlorpromazine is probably the drug of choice, but this possibility was overlooked.

Intubation may present certain hazards. The laryngoscope must be inserted carefully as the teeth in this disease are carious. It is preferable to use a Macintosh laryngoscope rather than a Magill so that trauma to the posterior surface of the epiglottis, with the resulting dangers of oedema and supralaryngeal obstruction, is prevented.

To avoid bullae formation, induction must be pleasant, smooth and rapid and struggling avoided. This is best achieved by intravenous thiopentone provided it is performed in a painless manner and the child is co-operative. The use of a face mask

FIG. 1
Epidermolysis bullosa dystrophica showing bullae on legs of a two-day-old baby.

FIG. 2
Lesions on tongue and nares arising from teat and tube feeding in the same baby eight months later.

FIG. 3
Bullae on ankle of patient suffering from epidermolysis bullosa dystrophica.

FIG. 4
Bullae formation and scarring on lips, tongue and chin of patient due to eating.

FIG. 5
Bullae formation and scarring on lips, tongue and chin of patient's brother.

FIG. 6
Atrophic scars on knees of patient's brother.

FIG. 7
Atrophic scars on elbow of patient's brother.

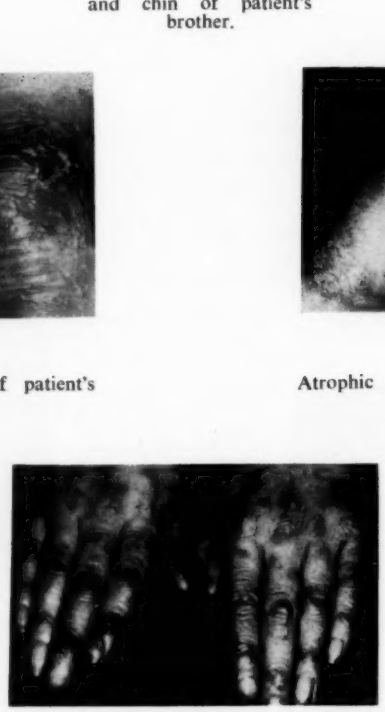

FIG. 8
Lesions on hands showing a deformed nail.

for induction is undesirable as bullae will form at the site of contact and under the chin due to the supporting fingers.

Oral intubation is less traumatic than if the endotracheal tube is introduced through the nose. Its smooth passage through the larynx is facilitated by means of a relaxant. If intubation is traumatic, bullae may arise within the larynx and spread down the trachea. Therefore it would appear to be dangerous to use an endotracheal tube whose circumference makes intimate contact with the larynx. Bullae arising with the tube in situ will probably rupture and become infected. If they arise after the tube has been withdrawn, an immediate tracheotomy may be necessary. The introduction of a tracheotomy tube, however, would cause a similar reaction and death might result from asphyxia.

The introduction of an oiled throat pack, if inserted carelessly, may cause bullae within the oral cavity. If it is placed posteriorly, it will occlude the nasopharynx so that the resistance arising from the use of a narrow bore endotracheal tube will give rise to a pronounced respiratory obstruction.

It is advisable to ensure that recovery is peaceful so that restraint is unnecessary. It appears, then, that the depth of anaesthesia should only be sufficient for the operation in question. Trichloroethylene has certain disadvantages in that it causes postoperative vomiting and is slowly excreted. When given in small quantities as in this case it gave satisfactory results.

Most of these cases are now treated on a.c.t.h. or cortisone but the dangers associated with this therapy have been fully described by Mushin (1957). The introduction of an endotracheal tube in the manner described above had no serious consequences. That it has been performed successfully in one case does not necessarily suggest it is a safe procedure.

A satisfactory from of anaesthesia in epidermolysis bullosa has not yet been described and at present one can only minimize the dangers incurred.

ACKNOWLEDGMENTS

I wish to thank Mr. F. E. Harrison, consultant Dental Surgeon to the Royal Liverpool Children's and Liverpool Dental Hospitals, for the advice he has given me regarding the preparation of this paper.

I am grateful to Mrs. R. R. Green, Photographer to Alder Hey Children's Hospital, for providing me with the photographs shown in figures 1 and 2. My thanks are also due to Mr. J. S. Bailie, Photographer to the School of Dental Surgery, University of Liverfor the photographs in figures 3 to 8.

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Brit. J. Anaesth. (1959), **31**, 32

AN OBSTETRIC ANAESTHETIC RECORD CARD

BY

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ANAESTHETIC records, it has been stated, may not only constitute an immediate distraction to an anaesthetist, but are of little use thereafter, for retrospective examination may fail to reveal some vital detail. These objections are not valid when the records to be kept are simplified, systematically completed and filed, and methodically planned for the purpose of some preconceived investigation.

The purpose of this communication is to describe a record card for obstetric anaesthesia which has been specifically designed to facilitate the recording of observations with the minimum of inconvenience and distraction, and which may, without reduplication, form part of the whole clinical record of mother and child. In designing this card I have drawn liberally on the experience and practice of others, and the card now used incorporates many useful factors that I have had the opportunity to see in use in other centres.*

Figure 1 shows the working face of the card. These particulars are reduplicated on a thin sheet loosely attached along the lower edge, which is separated from the card itself by a carbon during use. Subsequently the thin sheet is detached and by means of a pre-gummed strip along the upper edge is incorporated in the patient's clinical notes, both maternal and neonatal, by dividing along the vertical perforation. The size of the card (8 × 11 inches) corresponds to the size of the clinical notes in use.

On the patient's discharge the back of the card (see figure 2) is filled in and punched. At this time the clinical details are re-checked and the maternal and infant summaries added.

*Particularly in Professor R. A. Hingson's Department, Western Reserve University, Cleveland, Ohio.

DISCUSSION

This type of record offers advantages to all departments concerned with the care of mother and child. By this means a record of an important part of the clinical treatment, anaesthesia, is incorporated in the clinical file. The departments are provided with a simple and quick reference to the maternal and neonatal pre- and postoperative details in all cases involving operative obstetric procedures. These details, together with a history of the first few moments of life, the immediate postdelivery state, and the resuscitative measures employed, provide invaluable data for the anaesthetists, the obstetricians and the paediatricians.

After using this type of record for two years I have found that the practice not only disciplines the anaesthetist to make useful and accurate observation, but forms useful data for teaching and retrospective examination. In the event of either neonatal or maternal complications, each individual record forms the basis for examination and discussion.

In practice the records are easy to keep and with a stop-watch attached to the anaesthetic machine accurate time recordings can easily be made. We have found that the cards can readily be completed even by the single-handed anaesthetist.

SUMMARY

An anaesthetic record card is described which is simple to complete and allows clinical records of anaesthesia to be incorporated into the hospital notes without reduplication.

The advantages to all departments concerned in maternal and neonatal care are outlined.

ACKNOWLEDGMENT

The cards were prepared for me by the Copeland-Chatterson Company, of Stroud, Gloucestershire, to whom I am grateful for advice and assistance.

FIGURE. 1.

DATE 1. 1. 57.

NAME JONES. E.C.

PREMED. ATROPINE 1/100

ANAESTHETIC DURATION 35 MN

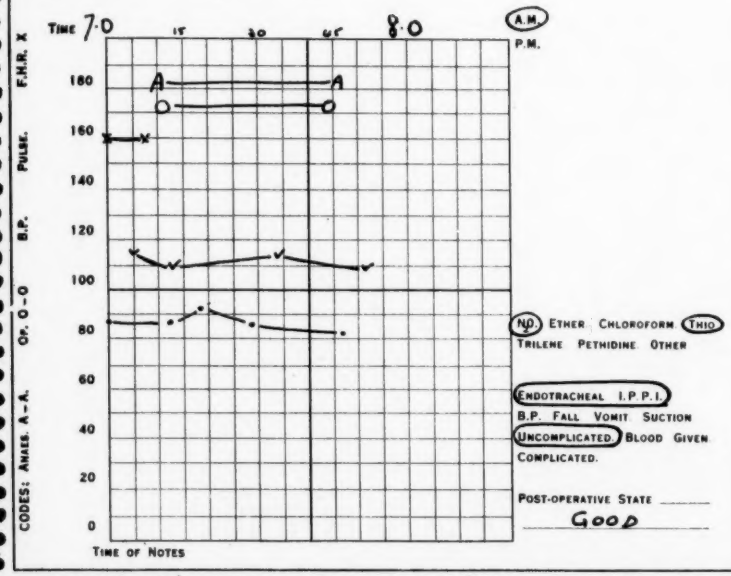
ANAESTHETIC TECHNIQUE

THIO-SUX-N_2O

OPERATIVE PROCEDURE

C.S FOR FOETAL DISTRESS IN 1ST STAGE.

NOTES .



(N$_2$O) ETHER CHLOROFORM (THIO)
TRILENE PETHIDINE OTHER

(ENDOTRACHEAL) I.P.P.I.
B.P. FALL VOMIT SUCTION
(UNCOMPLICATED) BLOOD GIVEN
COMPLICATED.

POST-OPERATIVE STATE
GOOD

ANAESTHETIST Ryan

PROCEDURE C.S FOR FOETAL DISTRESS IN FIRST STAGE

NAME JONES. E.C.

DRUGS GIVEN DURING ANAESTHETIC

DRUG	DOSE OR DURATION BEFORE DELIVERY	TOTAL DOSE OR DURATION
THIO	250 MG.	750
SUX	50+25+25 MG	350
N_2O	60% - 10 MN	

NEONATAL INFORMATION

MATERNAL PREMED. ATROPINE 1/100 I.V.

MATERNAL PREVIOUS DRUGS

PETHIDINE 100MG (6 HRS PRE-OP)

ANAESTHETIC INDUCED @ 0M 0S (7.10 AM.)

ANAESTHETIC TECHNIQUE THIO-SUX-N_2O

ANAESTHETIC COURSE UNEVENTFUL

DELIVERED @ 5M 10S

BREATHED @ 5M 15S

CRIED @ 5M 30S

RESUSCITATION

O_2 MASK ENDOTRACHEAL BOX

(ASPIRATION) I.P.P.I. LOBELINE

NIKETHAMIDE NALLORPHINE

CARDIAC MASSAGE. OTHER DRUG

FINAL CONDITION WT. 8.6.

(GOOD) FAIR POOR. IN / ON O_2

PORTSMOUTH GROUP HOSPITALS

OBSTETRIC — ANAESTHETIC RECORD

HOSPITAL NO S/99891 DATE 1.1.57

NAME JONES. E.C. PARA 0 E.D.D 14.1.57. AGE 27

HOSPITAL/WARD B.4. W/T. 11. 8.

BP 115/75 TPR 98°. 80. 20 HB 89% ALB. — oz

PROCEDURE C.S. FOR FOETAL DISTRESS IN FIRST STAGE.

SURGEON Jef ANAESTHETIST Rees

SUMMARY

MOTHER	NEONATE
Admitted in 1st Stage — spontaneous foetal distress. C.S — no incidents	Lusty male child (8.6.) delivered by C.S. No neonatal complicat^ns.

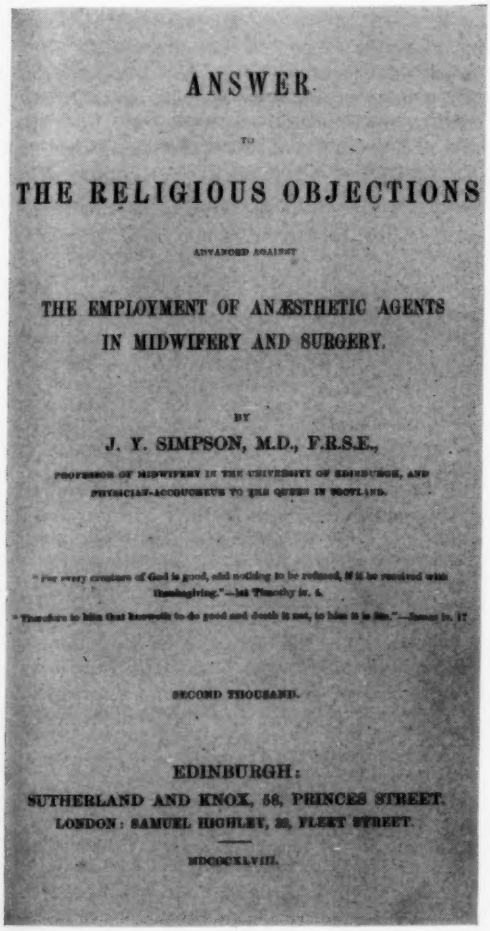
Left Hospital a.w. 10th day.

FIGURE. 2.

ANSWER TO THE RELIGIOUS OBJECTIONS ADVANCED AGAINST THE EMPLOYMENT OF ANAESTHETIC AGENTS IN MIDWIFERY AND SURGERY

BY

J. Y. SIMPSON



ANSWER

TO

THE RELIGIOUS OBJECTIONS

ADVANCED AGAINST

THE EMPLOYMENT OF ANÆSTHETIC AGENTS IN MIDWIFERY AND SURGERY.

BY

J. Y. SIMPSON, M.D., F.R.S.E.,

PROFESSOR OF MIDWIFERY IN THE UNIVERSITY OF EDINBURGH, AND PHYSICIAN-ACCOUCHEUR TO THE QUEEN IN SCOTLAND.

"For every creature of God is good, and nothing to be refused, if it be received with thanksgiving."—1st Timothy iv. 4.

"Therefore to him that knoweth to do good and doeth it not, to him it is sin."—James iv. 17.

SECOND THOUSAND.

EDINBURGH:

SUTHERLAND AND KNOX, 58, PRINCES STREET.

LONDON: SAMUEL HIGHLEY, 32, FLEET STREET.

MDCCCXLVIII.

Facsimile of the original title page.

Along with many of my professional brethren in Scotland, and perhaps elsewhere, I have, during the last few months, often heard patients and others strongly object to the superinduction of anæsthesia in labour, by the inhalation of Ether or Chloroform, on the assumed ground, that an immunity from pain during parturition was contrary to religion and the express commands of Scripture. Not a few medical men have, I know, joined in this same objection;* and have refused to relieve their patients from the agonies of childbirth, on the allegation that they believed that their employment of suitable anæsthetic means for such a purpose would be unscriptural and irreligious. And I am informed that, in another medical school, my conduct in introducing and advocating the superinduction of anæsthesia in labour has been publicly denounced *ex cathedra* as an attempt to contravene the arrangements and decrees of Providence, hence reprehensible and heretical in its character, and anxiously to be avoided and eschewed by all properly principled students and practitioners. I have been favoured with various earnest private communications to the same effect. Probably, therefore, I may be excused if I attempt, however imperfectly, to point out what I conscientiously conceive to be the errors and fallacies of those who thus believe that the practice in question ought in any degree to be opposed and rejected on religious grounds.

* "Pain during operations is, in the majority of cases, even desirable; its prevention or annihilation is, for the most part, hazardous to the patient. In the lying-in chamber, nothing is more true than this; pain is the mother's safety, its absence her destruction. Yet, there are those bold enough to administer the vapour of Ether, even at this critical juncture, forgetting it has been *ordered*, that 'in sorrow shall she bring forth.' "—(*On the "Injurious* (?) *Effects of the Inhalation of Ether;" in Edinburgh Medical and Surgical Journal for July* 1847, p. 258.)

It is almost unnecessary to begin with premising, that those who object to the superinduction of anæsthesia in parturition upon religious grounds, found their objections principally on the words of the primeval curse which God pronounced after the temptation and fall of our first parents. Few or none, however, of those who have most zealously urged the existence of this curse as a reason against the employment of anæsthetic means in obstetric practice, have, I believe, made themselves at all intimate with the words and tenor of the curse itself. I shall, therefore, in the first place, quote the words of it in full from the third chapter of Genesis, interpolating in Roman letters the Hebrew originals of those two nouns which are the more immediate subjects of doubt and difference of opinion.

GENESIS, chap. iii. v. 14.—"And the Lord God said unto the serpent, Because thou hast done this, thou art cursed above all cattle, and above every beast of the field; upon thy belly shalt thou go, and dust shalt thou eat all the days of thy life.

15. "And I will put enmity between thee and the woman, and between thy seed and her seed; it shall bruise thy head, and thou shalt bruise his heel.

16. "Unto the woman he said, I will greatly multiply thy sorrow (*'itztzabhon*) and thy conception; in sorrow (*'etzebh*) thou shalt bring forth children; and thy desire shall be to thy husband, and he shall rule over thee.

17. "And unto Adam he said, Because thou hast hearkened unto the voice of thy wife, and hast eaten of the tree, of which I commanded thee, saying, Thou shalt not eat of it; cursed is the ground for thy sake: in sorrow (*'itztzábhón*) shalt thou eat of it all the days of thy life:

18. "Thorns also and thistles shall it bring forth to thee; and thou shalt eat the herb of the field.

19. "In the sweat of thy face shalt thou eat bread, till thou return unto the ground; for out of it wast thou taken: for dust thou art, and unto dust shalt thou return."

In the form of a few separate observations, I will now add the remarks and answers which I wish to make. And I would begin by observing, that,—

1. The primeval curse is triple. It contains a judgment, First, upon the serpent (verses 14, 15); Secondly, upon the woman (v. 16); and, Thirdly, upon the ground for the sake of the man (v. 17-19).—With the first of these three curses—that on the serpent—and its apparent permanence (Isaiah lxv. 25), our present inquiry has nothing to do. It is enough for me to remark, that the second and third curses—on the woman and on the ground—are evidently, from different parts of the Holy Word, not immutable. God himself, on more than one occasion, promises the removal of them, and in general conjunctly, to the Israelites, provided they would keep their covenants and obey his laws. See, for example, Deuteronomy vii. 13, "I will bless the fruit of thy womb, and the fruit of thy land," &c.; xxviii. 4, "Blessed shall be the fruit of thy body, and the fruit of thy ground," &c. See also Chap. xxviii. 11, &c. In Isaiah (xxviii. 23-29), man's culture by the plough, &c., of the ground cursed by God, is said to come from the providence of God himself. "For his God doth instruct him to discretion, and doth teach him," (v. 26); and, "This also cometh forth from the Lord of hosts, which is wonderful in counsel and excellent in working" (v. 29).

2. Those who, from the terms of the first curse, argue against the superinduction of anæsthesia in labour, aver that we are bound to take and act upon the words of the curse *literally*. "I will greatly multiply thy sorrow and thy conception;" or as Gesenius and other Hebrew authorities state, that, being a case of Hendiadys, it may be *more* correctly rendered, "I will greatly multiply the sorrow *of* thy conception;* in sorrow thou shalt bring forth children." If, however, we are bound to take *this* part of the curse literally, and act accordingly, then we are bound to take and act also upon *all* other parts of the curse literally. If it is sinful to try to counteract the effects of this part of it, referring to child-bearing women, it is sinful to try to counteract the other parts of it, regarding the state of the ground, and the judgment upon man. The agriculturist, in pulling up "the thorns and thistles" which the earth was doomed to bear, so far tries to counteract that part of the primary doom; and yet is never looked upon as erring and sinning in doing so. Or grant, as I have heard argued, that he may be entitled to pull up "the thorns and thistles," because the curse further implies that he was doomed to till the ground,—still he was doomed to till it by "the sweat of his face." Now if, I repeat, the whole curse is, as is averred, to be understood and acted on literally, then man must be equally err-

* Augebo tibi *Graviditatis* molestias."—Dathe's Pentateuchus, p. 38.

ing and sinning, when, as now, instead of his own sweat and personal exertions, he employs the horse and the ox—water and steam power—sowing, reaping, thrashing, and grinding machines, &c., to do this work for him, and elaborate the "bread" which he eats. The ever active intellect which God has bestowed upon man, has urged him on to the discovery of these and similar inventions. But if the first curse must be read and acted on literally, it has so far urged him on to these improper acts by which he thus saves himself from the effects of that curse. Nay, more; if some physicians hold that they feel conscientiously constrained not to relieve the agonies of a woman in childbirth, because it was ordained that she should bring forth in sorrow, then they ought to feel conscientiously constrained on the very same grounds not to use their professional skill and art to prevent man from dying; for at the same time it was decreed, by the same authority and with the same force, that man should be subject to death,—"dust thou art, and unto dust shalt thou return." If, on the other hand, it be allowed that it is justifiable in the physician to try to counteract the effects of one part of the curse, and justifiable in the agriculturist to try to counteract the effects of another part, it is surely equally justifiable in the accoucheur to try to counteract the effects of a third part of it. But if, on the contrary, it is unjustifiable for him to follow out this object of his profession, it is equally unjustifiable for the physician and agriculturist to follow out the corresponding objects of their professions. Are those who maintain the uncanonical character of using human means to contravene the pains of childbirth ready, then, to maintain that we should not use human means to contravene the tendency to death, or to increase the fertility and produce of the ground except by personal labour, and the actual "sweat" of the brow? To be consistent, they must of necessity maintain this strange and irrational view of man, and of the duties and destinies which God has appointed for man. Or, otherwise, they must own that if it is right and meet in us to exert the human intellect so as to ameliorate the condition of man from the results of the fall, it is equally right and meet in us to employ the same means to ameliorate the condition of woman from the results of the same cause.

3. But does the word sorrow ("in sorrow thou shalt bring forth children") really mean physical and bodily *pain*, as is taken for granted by those who maintain the improper and irreligious character of any means used to assuage and annul the sufferings of childbirth? Now, the word "sorrow" occurs three several times in two consecutive verses of the curse; (verses 16 and 17). The corresponding word, or rather words, in the original Hebrew, as I have already shown when citing the terms of the curse, are *'etzebh*, and *'itztzabhon*. These nouns are both synonymous in meaning and origin, although longer and shorter in form (like labour, laboriousness—pain, painfulness—in our own language). All philologists agree that they are derived from the same root, viz., the verb *'atzabh*. The true and primitive meaning of a derivative word in the Hebrew, as in other languages, is generally the best attained by considering the signification of the root from which it is derived. The meaning of the verb *'atzabh* (the root of these nouns) is given as follows, by Professor Gesenius, the highest authority, I believe, I could quote on such a point. In his Lexicon he enters "*'atzabh*, 1. To *labour*, to *form*, to *fashion*. The original idea (says he) is perhaps that of cutting, whether wood or stones. 2. To *toil with pain*, to *suffer*, to be *grieved*; used also of the mind" (Tregelles' Translation of Gesenius' Hebrew and Chaldee Lexicon, p. DCXLVI). Of the disputed nouns the noun *'etzebh* ("in sorrow—*'etzebh*—thou shalt bring forth children") is nearest in form, and hence in meaning to the original verb-root *'atzabh*—and, I believe, no scholar would deem it erroneous to affix to it the same simple original signification "*labour*," "*toil*," without deeming it requisite to believe, that it at all farther necessarily imports that the implied labour and effort must essentially be to such an excess as actually to amount to the supervention of pain and agony. In fact, the Hebrew word for *labour* (in the sense of work or toil) is exactly like the English word *labour*, used also to import the act of parturition. Certainly, the greatest characteristic of human parturition as compared with parturition in the lower animals, is the enoromus amount of muscular action and effort (labour) provided for, and usually required for its consummation. The erect position (*vultus ad sidera erectus*) of the human

body, renders a series of peculiar mechanical arrangements and obstructions necessary in the human pelvis, &c., for the prevention of abortion and premature labour, and for the well-being of the mother during pregnancy. But these same mechanical adaptations and arrangements (such as the angle at which the pelvis is set to the spine,—the great difference in the axis of the pelvic brim, cavity, and outlet,—the rigidity of the soft structures, &c.) all render also, at last, the ultimate expulsion of the infant in labour, a far more difficult, and more prolonged process than in the quadruped, for instance, with its horizontal body. To overcome these greater mechanical obstacles, the human mother is provided with a uterus immensely more muscular and energetic than that of any of the lower animals. The uterus of woman is many times stronger and more powerful than the uterus, for example, of the cow. In other words, I repeat, the great characteristic of human parturition is the vastly greater amount of muscular effort, toil, or labour required for its accomplishment.* The state of anæsthesia does not withdraw or abolish that muscular effort, toil or labour; for if so, it would then stop, and arrest entirely the act of parturition itself. But it removes the physical pain and agony otherwise attendant on these muscular contractions and efforts. It leaves the labour itself (*'atzebh*) entire. And in relation to the idea, that the Hebrew noun in the text truly signifies muscular *toil* and effort, and not physical *pain* and maternal agony, it is further highly important to remark, that in the very next verse (verse 17), viz. in the first part of the curse on man, the analogous Hebrew noun (*'itztzabhon*), which we translate by "sorrow," assuredly does *not* in any degree mean or imply mortal suffering or pain, but toil and labour. "In sorrow thou shalt eat of it (the ground) all the days of thy life." Indeed, the very same noun (*'itztzabhon*), when it occurs with the same meaning, and in relation to the same curse two chapters onwards—Genesis v. 29—is, in our own version, rendered by the word "toil," and not "sorrow." "And he called his name Noah (rest or comfort), saying, This same shall comfort us concerning our work or toil (*'itztzabhon*) of our hands, because of the ground which our Lord hath cursed."

The word "sorrow" is a term at once simple and striking, but, at the same time, very comprehensive in its signification; and used under various specific meanings in our authorized English version of the Bible. In the Old Testament above twenty different terms or nouns in the original Hebrew text, are translated by the single term or noun "sorrow" in the English text.† And perhaps it may not be considered irrelevant, if I remark, that the identical Hebrew noun *'etzebh*, translated "sorrows" in the 16th verse ("in sorrow—*'etzebh*—thou shalt bring forth children"), recurs in six, and I believe only in six, other passages in the Old Testament; and in not one of these does it certainly imply physical pain. In two of these six places it is rendered, in our English version, by the very word "labour," in the signification of toil or work,—viz. in Prov. xiv. 23, "In all labour (*'etzebh*) there is profit;" and Prov. v. 10, "Lest thy labours‡ (*'etzebh*) be in the house of a stranger." In one passage it is translated "anger,"§ Prov. xv. 1, "Grievous words stir up anger (*'etzebh*)." In another passage in which it occurs, in Prov. x. 22, it is rendered sorrow, but still in the sense of toil and work—"The blessing of the Lord, it maketh rich, and he addeth no sorrow (*'etzebh*)‖ with it." In Psalms cxxvii. 2, it is also, in our English version, translated "sorrows"—"It is in vain for you to rise up early,

* In some of the black tribes of the human race the muscular efforts and exertions of the uterus seem to be accompanied with comparatively little or no physical pain—there is labour *without* suffering. But the black woman was cursed as well as the white; and surely it cannot be irreligious to *reduce* the sufferings of the civilized female to the degree and amount which nature has left them existing in the uncivilized female of our race. There are abundance of "maternal sorrows" connected with children and child-bearing in the civilized woman, quite independently of the actual agonies of parturition. My friend Dr Churchill of Dublin, some years ago, published a large octavo volume on the affections *peculiar* to the pregnant and puerperal states, without at all including those observable *during* labour.

† See a list of these various Hebrew words which the translators of the English Bible have rendered by the word "sorrow," in "The Englishman's Hebrew and Chaldee Concordance of the Old Testament," p. 1639.

‡ "Labours," *i.e.* "things done with toil."—*Gesenius*

§ "A word pronounced with anger—a bitter, sharp word."—*Gesenius.*

‖ That is, no "heavy and toilsome labour."—*Gesenius.*

and sit up late, to eat the bread of sorrows (*'atzabhim*, the plural of *'etzebh*)."* And, lastly, in Jeremiah xxii. 28, the same noun is translated "idol" (a thing made, worked, or fashioned), "Is this man Coriah a despised, broken idol (*'etzebh*)?"

The context, I repeat, in these six Biblical passages in which the noun *'etzebh* recurs, shows that in *them* the word is not, in any respect, employed to designate the *sensation* of pain which accompanies the act of parturition in the human female. And it is surely not an unfair or illegitimate deduction, to infer that in the only one remaining, or seventh instance in which the word occurs in the Bible—viz. in Genesis iii. 16—it would be used in the sense in which it is generally elsewhere used—of effort, toil, or labour—and not in a new sense, in which it is nowhere else used—of the *feeling* or perception of excruciating suffering, or bodily anguish.

4. But that the preceding deduction is sound and just, admits of additional, and still stronger corroborative evidence. In various passages in the Bible, the proverbial agony and pain of a woman in travail is brought in—and particularly in the inspired language of the Prophets—as a striking and beautiful simile, to mark the greatest possible degree of anguish and suffering. In not one of these passages, in which the pure pain and supersensitive suffering of the parturient mother are thus referred to, is the word in Genesis iii. 16, viz.—the word *'etzebh*—employed to designate this feeling of pain and suffering. Two other and totally different Hebrew nouns are used for this purpose in the passages to which I allude. These two nouns are *hhil* and *hhebhel*. They mark and designate the sensations of agony accompanying parturition, as contradistinguished from the muscular efforts (or labour) (*'etzebh*) in which the physiological part of the process of the expulsion of the child essentially consists. To illustrate the particular signification thus attached to the words *hhil* and *hhebhel*, as contradistinguished from *'etzebh*, I will cite the passages in which the two former nouns are used. In the following instances, the noun *hhil* is translated "pain," "pangs," &c.:—Psalm xlviii. 6, "Fear took hold upon them there, and pain as of a woman in travail." Jeremiah vi. 24, "Anguish hath taken hold of us, and pain as of a woman in travail." Jeremiah xxii. 23, "When pangs come upon thee, the pain as of a woman in travail." See, also, Jeremiah l. 43. Micah iv. 9, "Now why dost thou cry out aloud? is there no king in thee? is thy counsellor perished? for pangs have taken thee as a woman in travail." In the following instances, the noun *hhebhel* occurs in the original Hebrew with the same meaning attached to it:—Isaiah xiii. 8, "Pangs and sorrows shall take hold of them; they shall be in pain as a woman that travaileth." Isaiah xxvi. 17, "Like as a woman with child, that draweth near the time of her delivery, is in pain and crieth out in her pangs." See, also, Isaiah lxvi. 7; Jeremiah xiii. 21, and xlix. 23. Hosea xiii. 13, "The sorrows of a travailing woman shall come upon thee."

From what I have stated under the two preceding heads, we are then, I believe, justly entitled to infer that the Hebrew term which, in our English translation of the primaeval curse, is rendered "sorrow" (Genesis iii. 16), principally signifies the severe muscular *efforts* and *struggles* of which parturition—and more particularly human parturition—essentially consists; and does not specially signify the *feelings* or *sensations* of pain to which these muscular efforts or contractions give rise.—And, 2. On the other hand, the *feelings* or *sensations* of excruciating pain accompanying the process of parturition, are designated throughout the Bible by two Hebrew words which are entirely and essentially different from that term which is translated "sorrow," in the oft repeated expression—"in sorrow thou shalt bring forth children."

5. But even if—contrary to what, I think, the whole philological consideration of the very terms and words of the Bible shows to be the case—we were to admit that woman was, as the results of the primal curse, adjudged to the miseries of pure physical pain and agony in parturition, still, certainly under the Christian dispensation, the moral *necessity* of undergoing such anguish has ceased and terminated. Those who believe otherwise, must believe, in contradiction to the whole spirit and whole testimony of revealed truth, that the death and sacrifice of Christ was not, as it is everywhere declared to be, an all-sufficient sacrifice for all the sins and crimes of man. Christ, the

* "Bread obtained by toilsome labours."—*Gesenius.*

" man of sorrows," who " hath given himself up for us an offering and a sacrifice to God," " surely hath borne our griefs and carried our sorrows;" for God " saw the travail of his soul, and was satisfied." And He himself told and impressed on his disciples, that His mission was to introduce " mercy, and not sacrifice."—(See Matthew ix. 13; xii. 7; also Hos. vi 6). At the end of his commentary upon the curse in the third chapter of Genesis, the sound and excellent Matthew Henry, in his own quaint, pithy, and zealous style, justly observes, " How admirably the satisfaction our Lord Jesus Christ made by His death and sufferings, answered the sentence here passed upon our first parents. 1. Did *travailing pains* come in with sin? We read of the ' travail of Christ's soul;' Isa. liii. 11; and the pains of death he was held by, are called *ωδινας*, Acts ii. 24,—the ' pains of a woman in travail.' 2. Did *subjection* come in with sin? Christ was ' made under the law;' Gal. iv. 4. 3. Did the *curse* come in with sin? Christ was made ' a curse for us;' died a ' cursed death;' Gal. iii. 13. 4. Did *thorns* come in with sin? He was crowned with ' thorns ' for us. 5. Did *sweat* come in with sin? He sweat for us, ' as it had been great drops of blood.' 6. Did *sorrow* come in with sin? He was ' a man of sorrows;' his soul was in his agony ' exceeding sorrowful.' 7. Did *death* come in with sin? He became ' obedient unto death.' Thus is the plaister as wide as the wound. Blessed be God for Jesus Christ."—(*Exposition of the Books of Moses*, p. 19.)

6. It may not be out of place to remind those who oppose the employment of anæsthetic means in labour on supposed religious grounds, that on the very same grounds many discoveries in science and art—even in the medical art—have been opposed upon their first proposition; and yet, *now* that their first introduction is over, and the opinions and practices they inculcate are established, no one would be deemed exactly rational who would turn against the present or future *continuance* of their employment any such improper weapon. I might adduce many instances, but one may suffice for all. When small-pox inoculation was introduced towards the commencement of the last century, the Rev. Mr Delafaye and Mr Massey published sermons against the practice as indefensible, on religious as well as medical grounds.* Inoculation was declared a " diabolical operation," and a discovery sent into the world by the Powers of Evil. And, again, when Dr Jenner introduced vaccination instead of small-pox inoculation, towards the commencement of the present century, theological reasons again were not wanting for calling in question the orthodoxy of this other new practice. " Small-pox (argued Dr Rowley) is a visitation from God, and originates in man, but the cow-pox is produced by presumptuous, impious man. The former, heaven ordained; the latter is perhaps a daring and profane violation of our holy religion." And he subsequently proposed, "whether vaccination be agreeable to the will and ordinances of God, as a question worthy of the consideration of the contemplative and learned ministers of the gospel of Jesus Christ; and whether it be impious and profane, thus to wrest out of the hands of the Almighty the divine dispensation of Providence!"† " The projects of these vaccinators seem (it was affirmed) to bid bold defiance to heaven itself, even to the will of God."‡ " Providence (reasoned another author) never intended that the vaccine disease should affect the human race, else *why* had it not, before this time, visited the inhabitants of the globe. The law of God (he continues) prohibits the practice; the law of man and the law of nature loudly exclaim against it."§

Such historical facts and efforts, and the results in which they have invariably terminated, are surely sufficient to make men cautious and hesita-

* See Delafaye's Sermon on "Inoculation; an Indefensible Practice." Massey's "Sermon against the Dangerous and Sinful Practice of Inoculation." In his admirable "Account of the Inoculation of Small-pox in Scotland (1765)," Dr Monro (*primus*) states "The first and most general prejudice against inoculation is its being deemed a tempting of God's providence, and therefore a heinous crime."—P. 5. "Clergymen (observes Dr Baron, in his Life of Jenner, vol. i. p. 231) preached from their pulpits in this style of argument, if so it might be called. Some went so far as to pronounce inoculation an invention of Satan himself, and its abettors were charged with sorcery and atheism. These things (he adds) would scarcely obtain credence were it not that similar arguments and assertions have been employed against Vaccination itself."

† Blair's Vaccine Contest, p. 84.

‡ Rowley on "Cow-pox Inoculation; with the Modes of treating the Beastly new Diseases produced by it." p. 9.

§ Dr. Squirrell's Preface to the Second edition of his "Observations on Cow-pox, and the dreadful consequences of this new Disease," p. iv.

ting against always recklessly calling up again the same religious, or supposed religious, arguments under the same circumstances.* Views and arguments of this description against every new practice intended to increase the well-being and happiness of mankind, certainly are greatly more calculated to inflict damage than benefit upon the interests of true religion.

Probably I may here be excused adding, that my friend Professor Miller informs me, that when reluctantly consenting to write the elaborate article on Etherization, which he afterwards penned for the North British Review (No. for May 1847), he stated to the late Dr Chalmers, who solicited him to undertake the task, that if he " wrote the medical Dr Chalmers should himself write the theological part." Dr Chalmers at once professed that he did not see any theological part pertaining to it. Mr Miller then explained to him, that some had been urging objections against the use of ether in midwifery on the ground of its so far improperly enabling woman to avoid one part of the primeval curse. At last when Mr Miller was enabled to convince him that he was in earnest in saying that such ground *had* been taken, Dr Chalmers thought quietly for a minute or two, and then added, that if some " small theologians " really took such an improper view of the subject, he would certainly advise Mr Miller not to " heed them " in his article. Dr Chalmers' mind was not one that could take up or harbour the extraordinary idea, that, under the Christian dispensation, the God of Mercy should wish for, and delight in, the sacrifice of women's screams and sufferings in childbirth. Perhaps he thought also, as I have heard other clergymen state, that if God has beneficently vouchsafed to us a means of mitigating the agonies of childbirth, it is His evident intention that we should employ these means. The very fact that we have the power by human measures to relieve the maternal sufferings, is in itself a sufficient criterion that God would rather that these sufferings be relieved and removed. If He had willed and desired them not to be averted, it would not be possible for man to avert them. For while it is our duty to avoid all misery and suffering that is avoidable, it would certainly be impossible for us to eschew any that God had permanently and irreversibly decreed should not be eschewed.

7. I have heard objections urged against the state of anæsthesia as a counteraction to pain in surgery and midwifery, on other and different grounds from any which I have yet noticed, viz., that in superinducing a temporary absence of *corporeal* sensibility, we also superinduce, at the same time, a temporary absence of *mental* consciousness. And it is argued that, as medical men, we are not entitled to put the activity and consciousness of the mind of any patient in abeyance, for the mere purpose of saving that patient from any bodily pain or agony. Some medical men even, have gravely pressed this argument. But if there were any propriety in it, why, then, these same medical men could never have been justified in doing what they have, one and all of them, done perhaps hundreds of times; viz. exhibit, by

* Perhaps, in the history of misplaced religious arguments against all novel opinions and practices, none in the retrospect may appear stranger than one that has been repeatedly mentioned to me during the few past months. Formerly, among my countrymen, most agricultural operations were performed, as commanded in the primeval curse, by personal exertion, and the "sweat of the face." Corn, in this way, was winnowed from the chaff by tossing it repeatedly up into the air, upon broad shovels, in order that any accidental currents which were present might carry off the lighter part. At last, however, about a century ago, "fanners," or machinery made for the production of *artificial* currents to effect the same purpose, were invented and introduced into different parts of the country. Some of the more rigid sects of Dissenters loudly declaimed against the employment of any such machinery. "Winds (they argued) were raised by God alone, and it was irreligious in man to attempt to raise wind for the aforesaid purpose for himself, and by efforts of his own." Mr. Gilfillan, the well-known Scottish poet, has furnished me with evidence of one clergyman debarring from the communion of the Lord's Supper those members of his flock who thus irreverently used the "Devil's wind" (as it was termed). And such sentences, I believe, were not uncommon almost within the memory of some aged members of the present generation. Sir Walter Scott, in his Old Mortality, introduces honest Mause Headrigg as charging the Lady Margaret Bellenden and the authorities at Tillietudlem with abetting this reprehensible practice. "And since your leddyship is pleased to speak o' parting wi' us, I am free to tell you a piece o' my mind in another article. Your leddyship and the steward hae been pleased to propose that my son Cuddie suld work in the barn wi a new-fangled machine for dighting the corn frae the chaff, thus impiously thwarting the will of the Divine Providence, by raising wind for your leddyship's ain particular use by human art, instead of soliciting it by prayer, or waiting patiently for whatever dispensation of wind Providence was pleased to send upon the sheeling hill." (*Chap.* vii.)

the mouth, opium and other narcotics and hypnotics to their patients, to mitigate pain and superinduce anæsthesia and sleep. There is no greater impropriety or sin in producing sleep and freedom from pain by exhibiting a medicine by the mouth, than by exhibiting it by the lungs. There is *less* impropriety in the latter practice than in the former, even according to the very doctrine of these opponents. For narcotic or anæsthetic agents which are swallowed, are far more prolonged in their "insensibilizing" action upon both the mind and body than those that are inhaled. The questionable character of the practice (supposing it for a moment to be questionable), must be much less when the effect is short and evanescent, as with ether and chloroform when respired; than when it is long and protracted, as with opium, morphia, henbane, &c., when swallowed. The proper anæsthetic state is one physiologically and psychically analogous to natural deep sleep. It is an artificial deep sleep. Those who object and urge that we should never follow ourselves, or induce others to follow, the practice of voluntarily surrendering up our mental consciousness for a time, in order to avoid any corporeal torture or agony that we would otherwise endure during that time, forget how often and how long they and others are in the habit of voluntarily surrendering up their mental consciousness in common sleep, far, far beyond the time required merely for the refreshment and renovation of the system. Many thus *daily* surrender their minds and reason up for unnecessary hours to the state of unconsciousness existing in common or natural sleep, without any object except the reprehensible indulgence of sloth and indolence: and then they turn round, and declaim against others having induced upon them, at some *rare* and extraordinary time, the unconsciousness of artificial sleep, when there is a great and laudable object in view,—viz. the avoidance of excruciating corporeal suffering, and the saving of human life, by saving the human system from the shock and dangers accompanying that suffering.* Besides those that urge, on a kind of religious ground, that an artificial or anæsthetic state of unconsciousness should not be induced merely to save frail humanity from the miseries and tortures of bodily pain, forget that we have the greatest of all examples set before us for following out this very principle of practice. I allude to that most singular description of the preliminaries and details of the first surgical operation ever performed on man, which is contained in Genesis ii. 21:—"And the Lord God caused a deep sleep to fall upon Adam; and he slept; and he took one of his ribs, and closed up the flesh instead thereof." In this remarkable verse the whole process of a surgical operation is briefly detailed. But the passage is principally striking, as affording evidence of our Creator himself using means to save poor human nature from the unnecessary endurance of physical pain. "It ought to be noted (observes Calvin in his commentary on this verse), that Adam was sunk into a profound sleep, in order that he might feel no pain."† In his collected commentaries on the same verse, Pool quotes different authorities for the same opinion, that this deep sleep was induced upon Adam in order that "he might not feel pain from the removal of the rib."‡ And the *profundity* of the sleep, as expressed in the Hebrew, is also worthy of note. For the noun "*tardemah*," translated in our version "deep sleep,"§ signifies, according to all the best Hebrew scholars, the deepest form of induced slumber. In the early and very literal Greek translation which Aquila made of the Bible, he renders, in this passage, the Hebrew word *tardemah* by the expressive Greek term κατάφορα, a term which Hippocrates, Galen, Ætius, and

* See evidence of its saving human life, as well as saving human suffering, under surgical operations, in a table which I have given of the results of amputations with and without etherization, at p. 11 of "Remarks on the Superinduction of Anæsthesia in Natural and Morbid Parturition" [p. 594 of Journal].

† "Notandum, Adam profundo sopore fuisse demersum, ut nihil doloris sentiret."—*Johannis Calvini in Librum Geneseos Commentarius* (Hengstenberg's Edit. p. 36).

‡ "Ne ablationis costæ dolorem sentiret."—*Poli Synopsis Criticorum aliorunque Scripturæ Interpretum.* Vol. I. p. 29.—See also the same opinion expressed in Rosenmuller's *Scholia Vetus in Testamentum*, vol I. p. 106. "Adamo, somno sopito, ne dolorem sentiret:" and in the English Commentaries of Bishop Patrick, p. 14, "Whereby he was made less sensible of the pain, which otherwise he would have felt in the opening his side;" and of Drs D'Oyly and Mant, "Adam was thus less sensible of bodily pain;" &c. &c.

§ In Luther's German Bible, an exactly corresponding expression "*tiefen schlaf*" is used. In Dathe's valued Latin version of the Pentateuch, a similar translation is given, "*Deus gravem Adamo soporem immisit*," p. 27.

other Greek physicians, used as implying that state of deep insensibility and total unconsciousness which in modern medical language we express by "coma" and "lethargy."* Gesenius renders *tardemah* by the Latin word "sopor," the Hebrew term for common sleep being *shenah*. In the Vulgate it is translated "sopor" (*immisit Deus soporem in Adam*). In the quotation which I have given from Calvin, that great authority renders the term *tardemah* by the expression, profound "sopor" (*profundo sopore*); and Pool quotes different authorities to show that the Hebrew word does signify "sopor" of a profound kind, "*notat profundum soporem.*"†

* "Cataphora (from καταφερω to sink or fall down,) a term used by some authors to designate a state of coma, and by others an unusually profound sleep."—*Hooper's Medical Dictionary.*

† See his *Synopsis Criticorum et Scripturæ Interpretum*, p. 29.

BOOK REVIEW

Electronic Apparatus for Biological Research. By P. E. K. Donaldson. Published by Butterworth's Scientific Publications. Pp. xii + 718; 120*s*.

In centres undertaking serious research in anaesthesia the use of electrical and electronic techniques is becoming routine. As a result it is helpful for anaesthetists to have some understanding of electronic circuits, and this is often acquired through a knowledge of amateur radio. This approach is not best united to the low frequency circuits usually encountered in medical measuring equipment. A copiously illustrated book such as this fills a definite need for a reference book in a busy laboratory.

It must be pointed out, however, that the book has been written by a specialist in electrophysiology. Thus it is intended mainly for workers in general physiology and does not deal with respiratory measurements in particular.

Part I deals with the principles of all the circuits commonly encountered in biological work. The treatment is rigorous and reinforced by plenty of numerical examples. The range covered is wide, starting from Ohm's Law and elementary valve circuits and proceeding to the theory of biological amplifiers, oscillators, time bases and pulse generators.

Part II discusses circuit components, chassis construction, circuit layout and workshop practice. The detailed information given will be found useful.

Part III contains chapters by a number of contributors. It covers transducers, glass microcapillary electrodes for measuring potential in living tissues, measurement and control of temperature, relays, light sources and measurement of radioactivity. The chapters on temperature and relays are particularly good. A more detailed treatment of the versatile Velodyne motor control system would be advantageous.

Part IV deals with practical circuits for laboratory use. The design of biological amplifiers, stabilized power units and transistor circuits is well covered. In view of the fact that the cathode ray oscilloscope is widely used in biological experiments, some time base circuits with component values might well have been included.

In the preface the author states that the emphasis of his book is on techniques. Readers would have benefited from some practical details of such techniques as using an oscilloscope, the effect of needle or catheter size on blood pressure recordings, and the calibration of pressure transducers.

D. W. Hill

MANCHESTER MEDICAL SOCIETY

Anaesthetics Section

The following meetings will be held in Staff House of the University of Manchester at 8 p.m.

Thursday, February 19	Professor W. D. M. Paton: "The Effects of Halothane on Autonomic Nervous Activity."
Thursday, March 19	Dr. G. J. C. Brittain: "The use of the Postoperative Recovery Ward."

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